

# Precipitation Processing System (PPS)



## NASA Global Precipitation Measurement (GPM) Microwave Imager (GMI) Level 1B (L1B) Algorithm Theoretical Basis Document (ATBD) Version 1.0 (PPS V03C Production)

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## REVISION HISTORY

### **Revision 3, Version 1.0, September 2014, Applied to PPS production V03C**

In this revision, using post-launch deep space maneuver data, BATC/RSS provided correction algorithm to correct errors induced by an instrument susceptibility to magnetic fields (Section 2.4). There are also along scan corrections on main reflector antenna patterns (Section 2.2). Post launch validation (Section 2.5) is revised to include analyses of GMI Ta/Tb data in the September public release. Algorithm of detecting RFI on cold load are also revised (Section 2.1.5). In Section 1, Spectrum Response charts for all channels are added.

### **Revision 2, Version 0.4, June 2014**

In this revision, the GMI L1B algorithms have been updated with new Ball sensor data and code updates for the public release on June 16, 2014. Sections 2.1.5 and 2.1.6 have been updated accordingly to comply with the algorithm updates, including new Table 2.9, Maximum values for correction code computation, and new Figure 2.5, Sample GMI 10 GHz V channel Ta (upper) and 166 GHz V channel Ta (lower).

### **Revision 1, Version 0.3, April 2014**

In this revision, post-launch studies from BATC/RSS provided new tables of on-orbit hot/cold sample ranges (Table 2.4, Hot load sampling, and Table 2.6, Cold sky sampling). Non-linearity look-up tables (Appendix A) and diode excess temperature look-up tables (Appendix C) are also updated. The number of scans to be averaged in multi-scan calibration is also revised (Section 2.1).

## 1. INTRODUCTION

### 1.1 OBJECTIVE

This document describes the GMI Level 1B algorithm developed in PPS. It consists of physical bases and mathematical equations for GMI calibration, as well as after-launch activities. The document also presents high-level software design. Parts of this document are from the RSS GMI Calibration ATBD and the BATC Calibration Data Book as contributed by the BATC GMI manufactory contract. The GMI L1B geolocation algorithm is described in a separate Geolocation Toolkit ATBD.

### 1.2 INSTRUMENT DESCRIPTION

GMI is a conically scanning microwave radiometer on board the GPM core satellite. The core satellite flies in a 407-km circular orbit with a 65° inclination angle. The GMI has 13 channels at frequencies of 10.65, 18.7, 23.8, 36.64, 89, 166 and 183.31 GHz. Except the heritage hot load and cold load that are commonly used for linear sensor radiometric calibrations, hot noise diodes and cold noise diodes are implemented in the GMI to determine the non-linearity and noise levels of the measurements. Figure 1.1 and Figure 1.2 show the main components of the GMI.

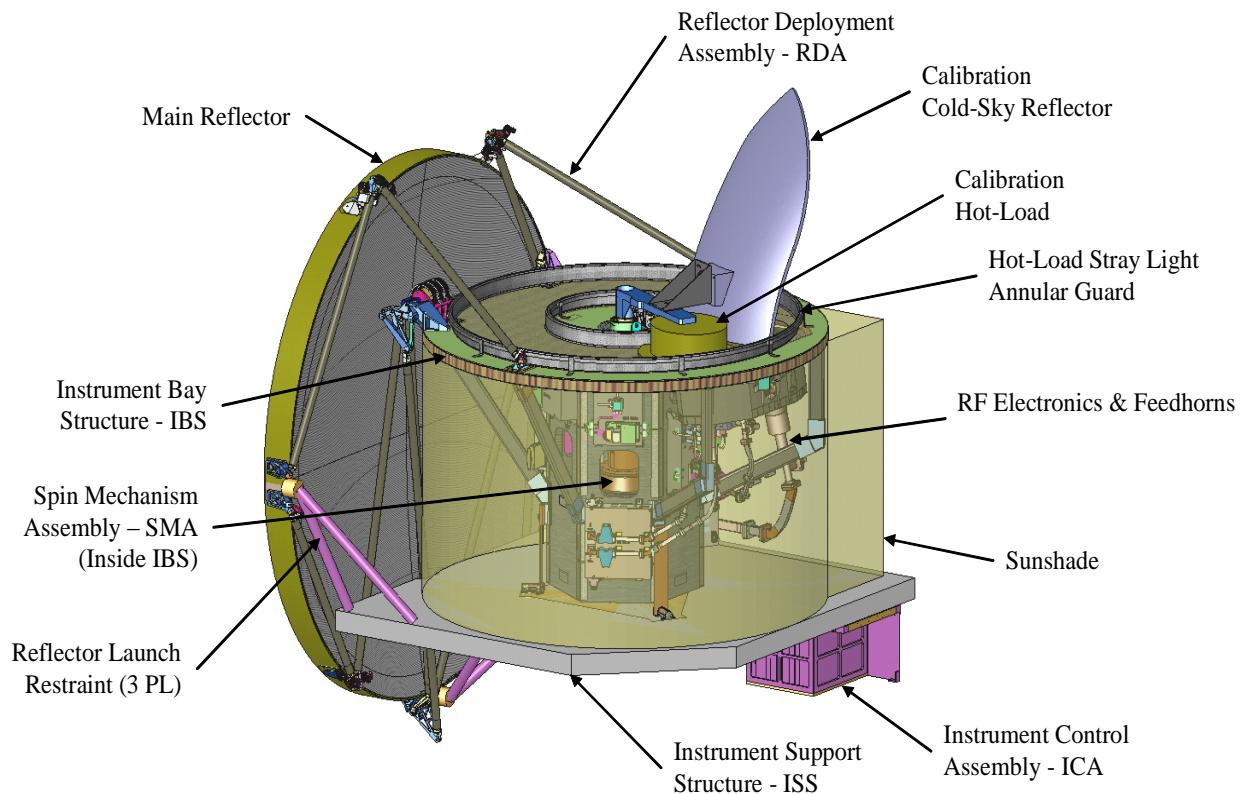
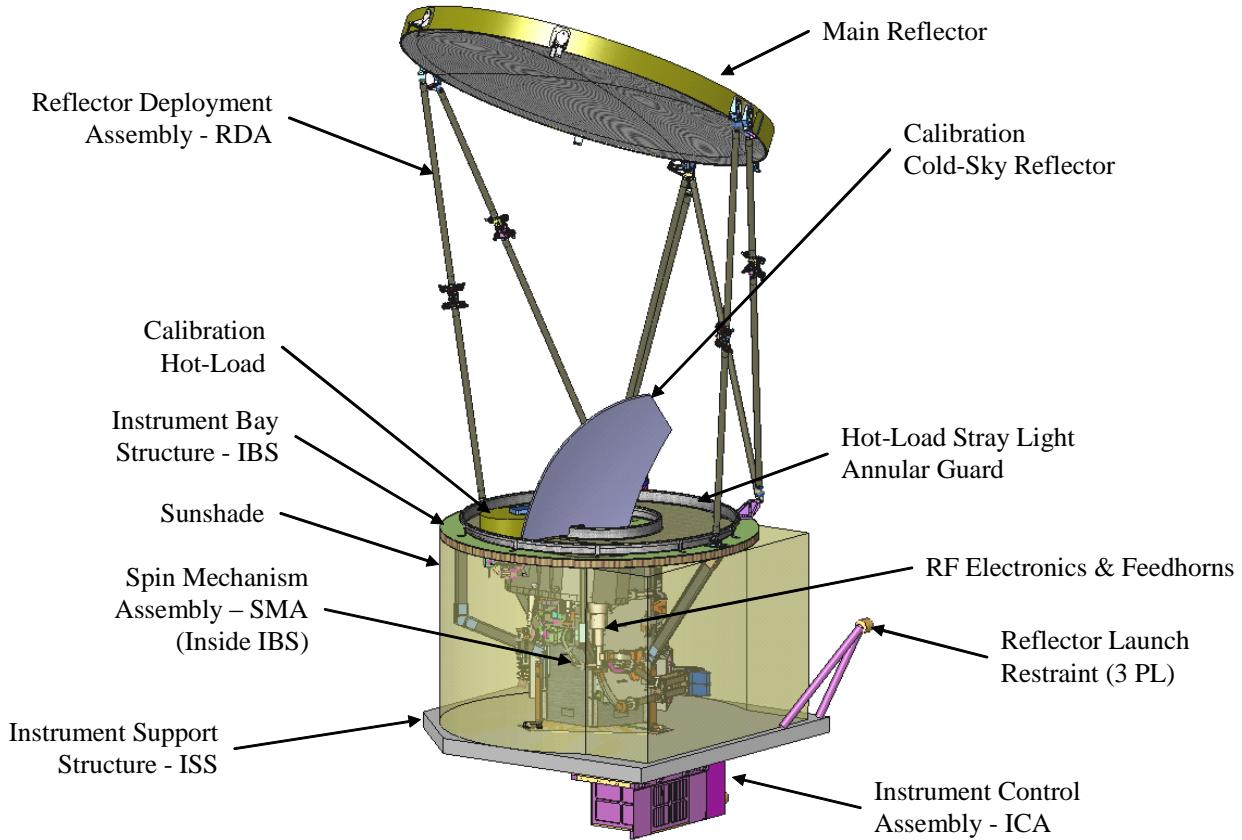


Figure 1.1. GMI instrument stowed configuration; provided by BATC.



**Figure 1.2. GMI instrument deployed configuration; provided by BATC.**

Key GMI sensor data include:

Nominal altitude: 407 km  
Orbital inclination: 65 deg  
Spin Rate: 32 rpm  
Scan Time: 1.875 sec  
Earth Swath width: 885 km  
Earth viewing sector: 145 deg  
Earth samples: 221  
Integration time: 3.6 msec  
Dish Size: 1.22 m

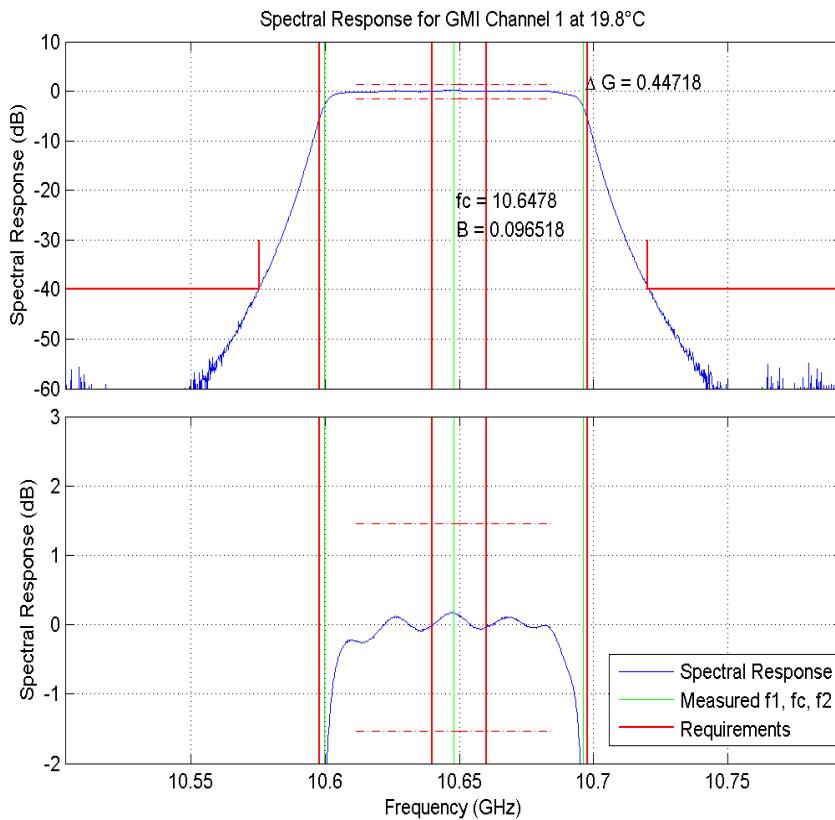
The GMI 1Base file includes also antenna temperature of full rotation swaths (about 500 samples). Some of the important sensor specifications can be found in Table 1.1.

**Table 1.1. Reference for important instrument and orbital parameters.**

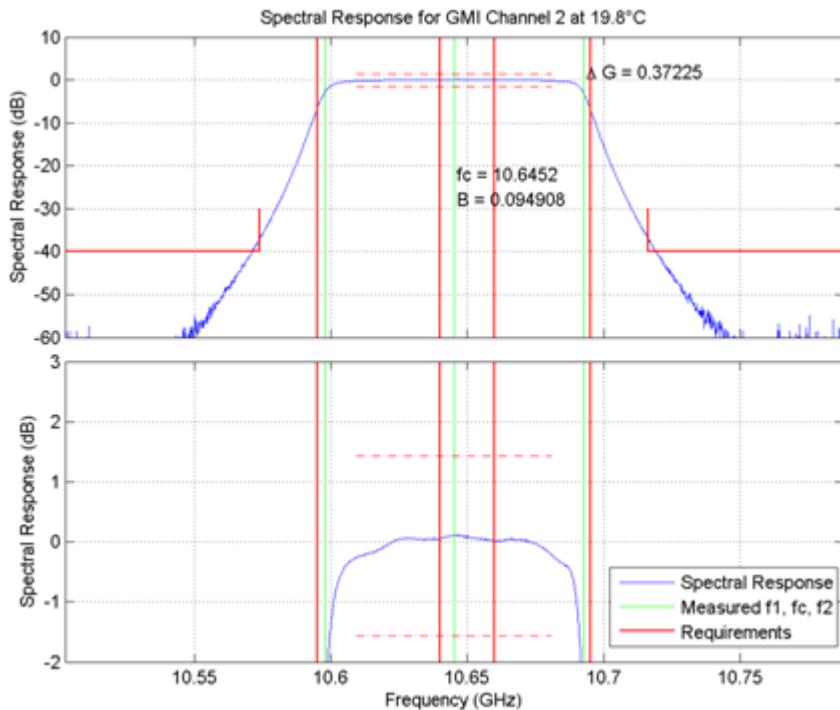
Channel #	Center Frequency (GHz)	pol	Nadir Angle (degree)	Earth Incidence Angle (degree)	Beam width (degree )	Footprint (km×km)	Cold samples per scan	Hot samples per scan	Earth samples per scan	Band width (MHz)
1,2	10.65	v/h	48.5	52.821	1.72	32.1×19.4	19/25	13/19	211/221	100
3,4	18.7	v/h	48.5	52.821	0.98	18.1×10.9	31/37	13/19	211/221	200
5	23.8	v	48.5	52.821	0.85	16.0×9.7	31/37	13/19	211/221	400
6,7	36.64	v/h	48.5	52.821	0.81	15.6×9.4	45/51	19/25	211/221	1000
8,9	89	v/h	48.5	52.821	0.38	7.2×4.4	45/51	25/31	211/221	6000
10,11	166	v/h	45.36	49.195	0.37	6.3×4.1	45/51	27/33	211/221	4000
12	183.31 ±3		45.36	49.195	0.37	5.8×3.8	45/51	27/33	211/221	2000
13	183.31 ±7		45.36	49.195	0.37	5.8×3.8	45/51	27/33	211/221	2000

For number of samples, the first is for radar blanking on and the second is for radar blanking off. However, the cold and hot sample tables are revised after launch (see Table 2.6 and Table 2.4 for best samples used in calibration).

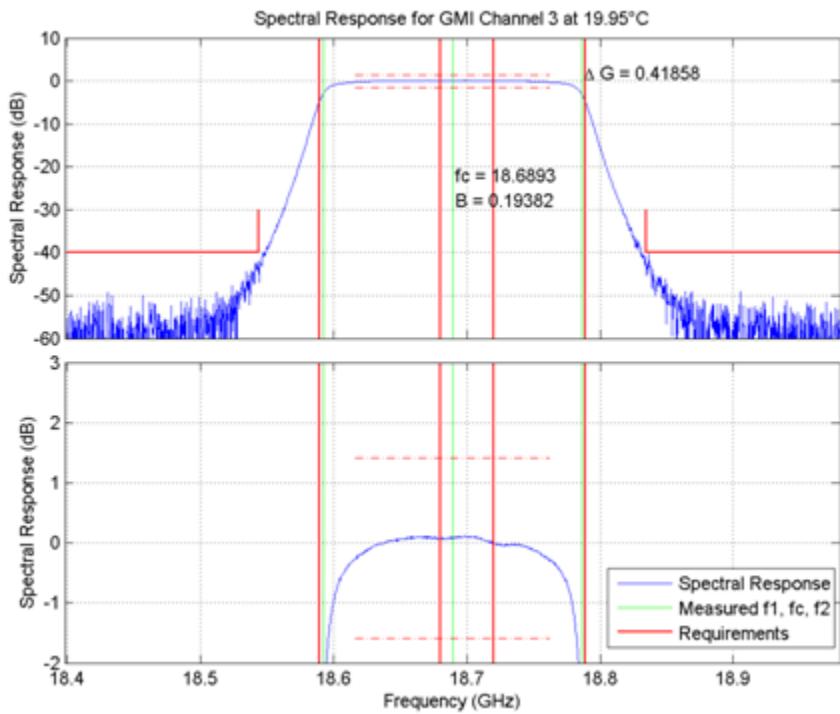
Figure 1.3 to Figure 1.15 demonstrates the typical spectral response of 13 GMI channels.



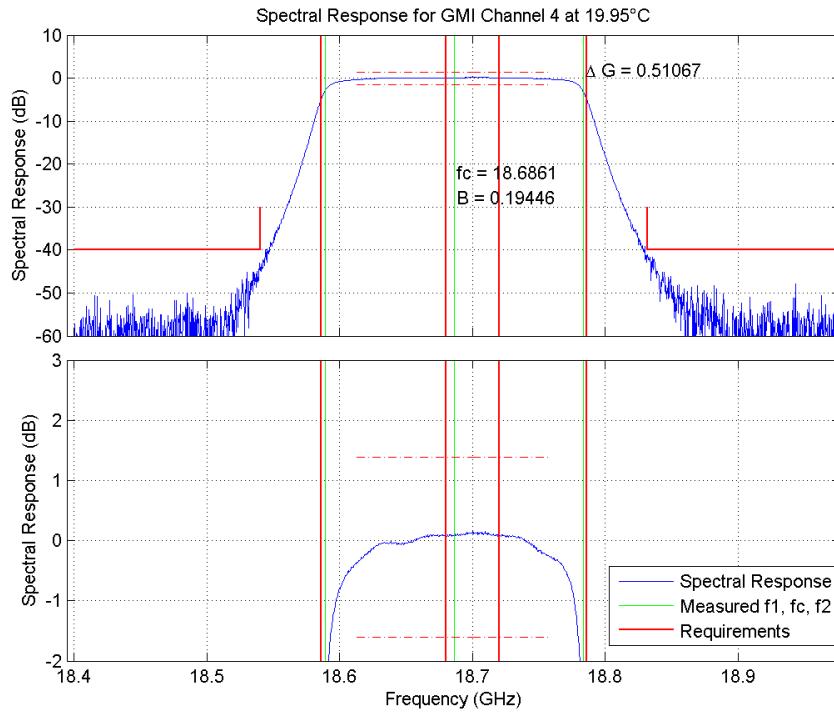
**Figure1.3. Band-pass and gain variation verification data for Channel 1 at 19.8°C**



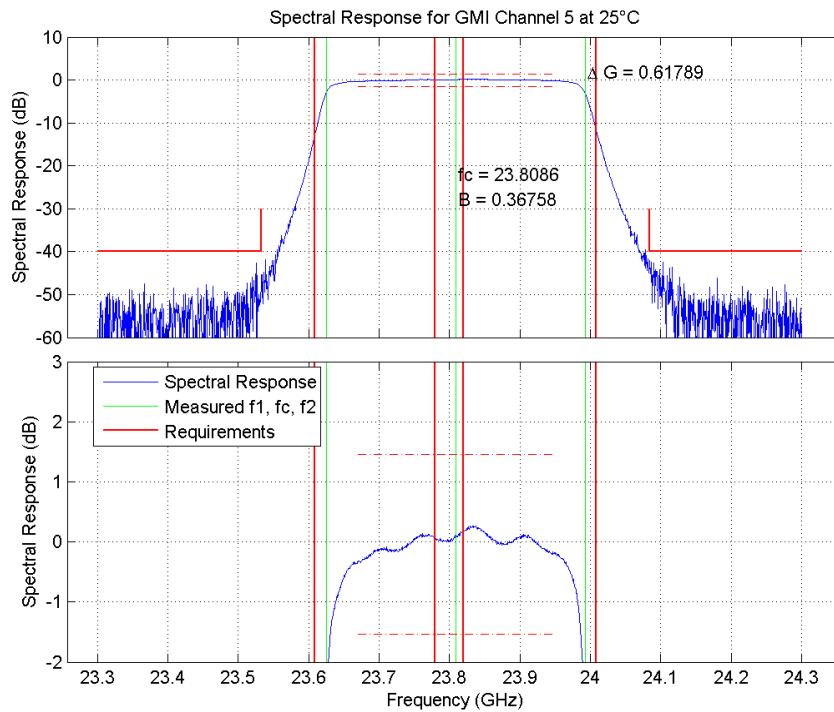
**Figure1.4.** Band-pass and gain variation verification data for Channel 2 at 19.8°C



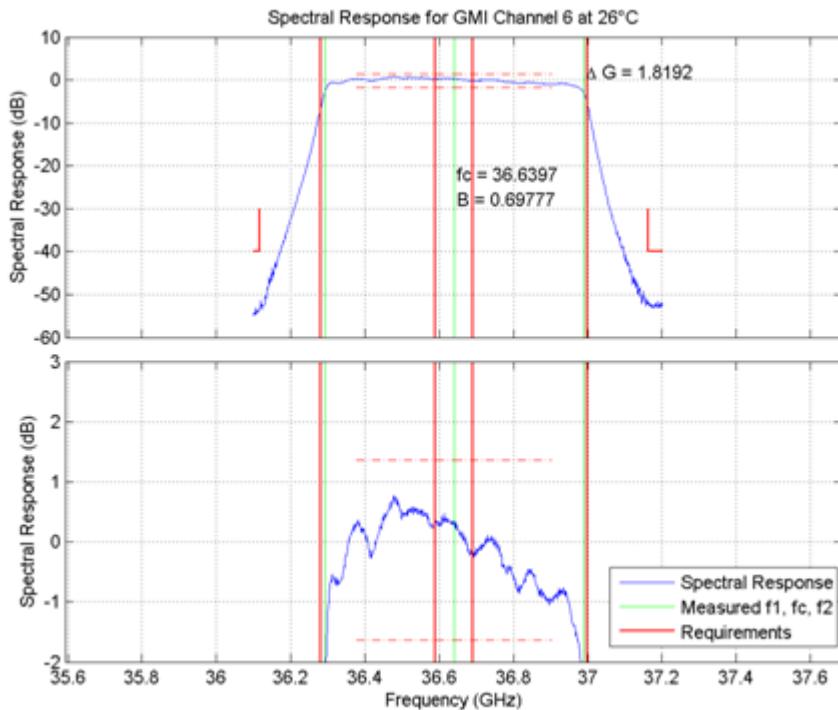
**Figure1.5.** Band-pass and gain variation verification data for Channel 3 at 19.95°C



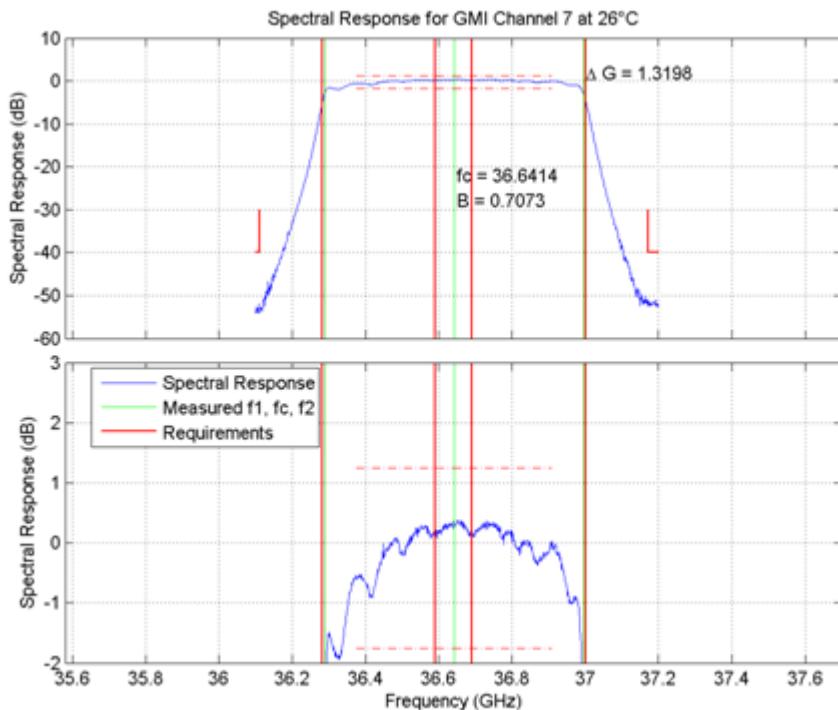
**Figure1.6. Band-pass and gain variation verification data for Channel 4 at 19.95°C**



**Figure1.7. Band-pass and gain variation verification data for Channel 5 at 25°C**



**Figure 1.8. Band-pass and gain variation verification data for Channel 6 at 26°C**



**Figure 1.9. Band-pass and gain variation verification data for Channel 7 at 26°C**

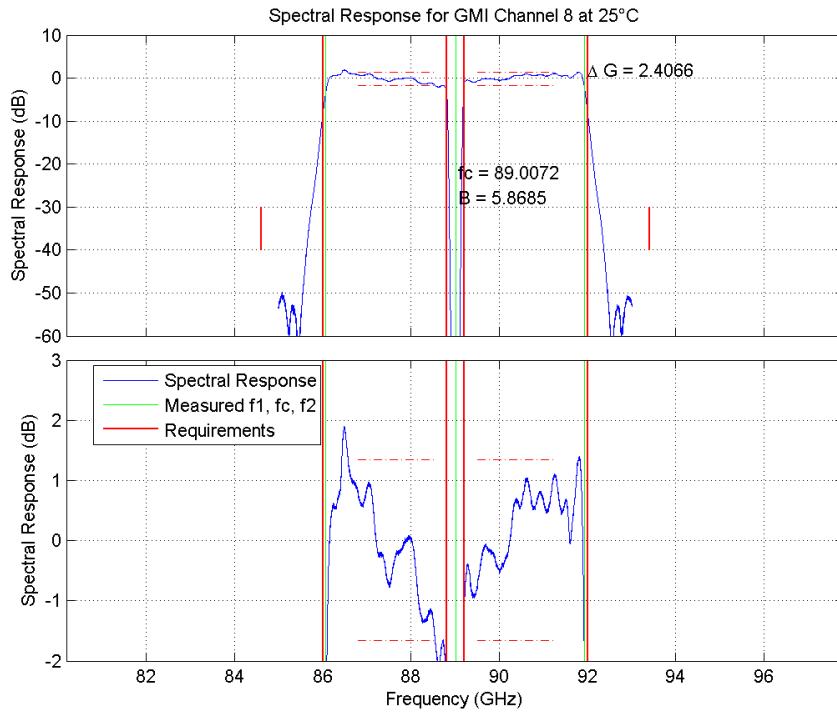


Figure1.10. Band-pass and gain variation verification data for Channel 8 at 25°C

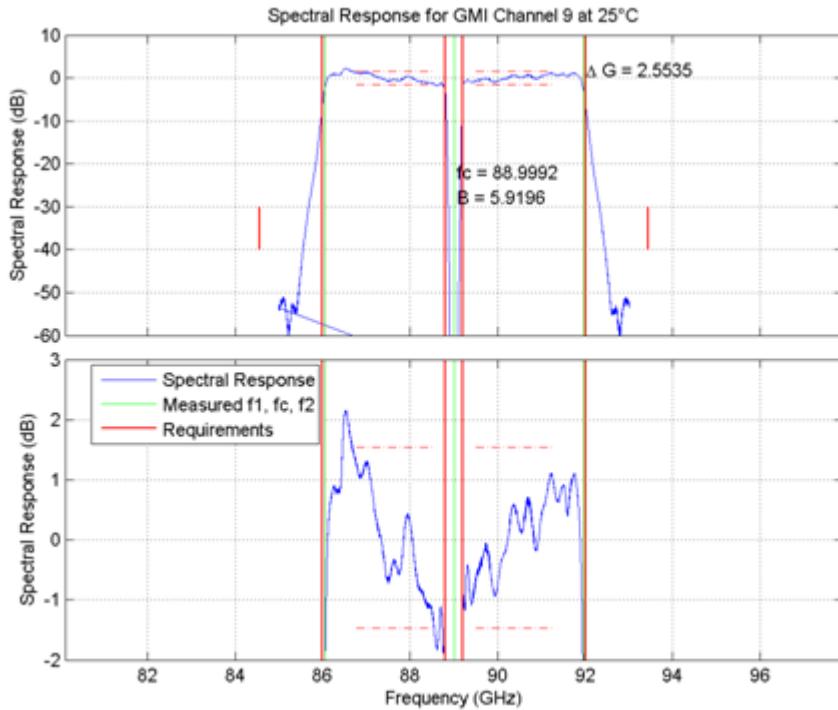
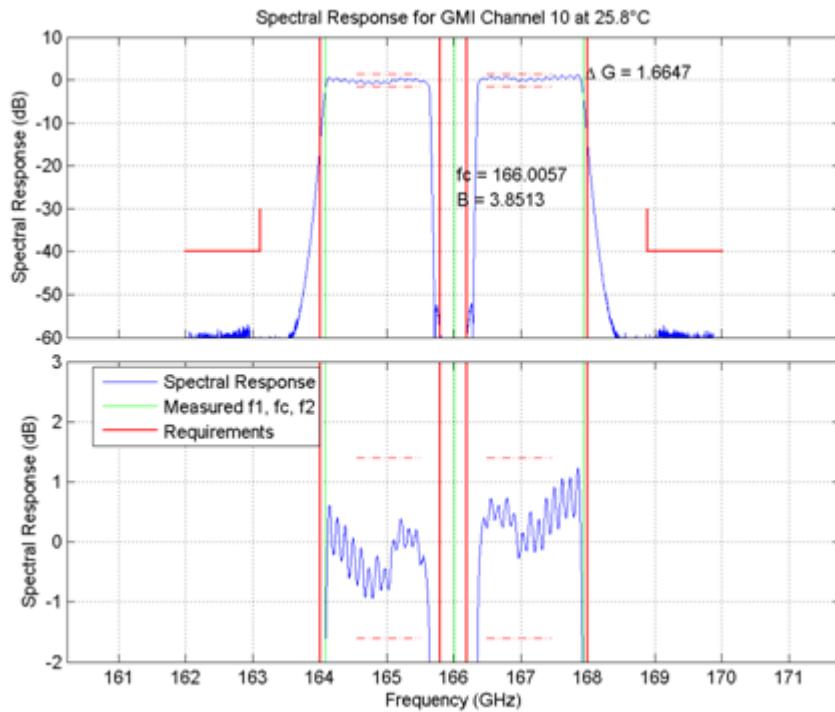
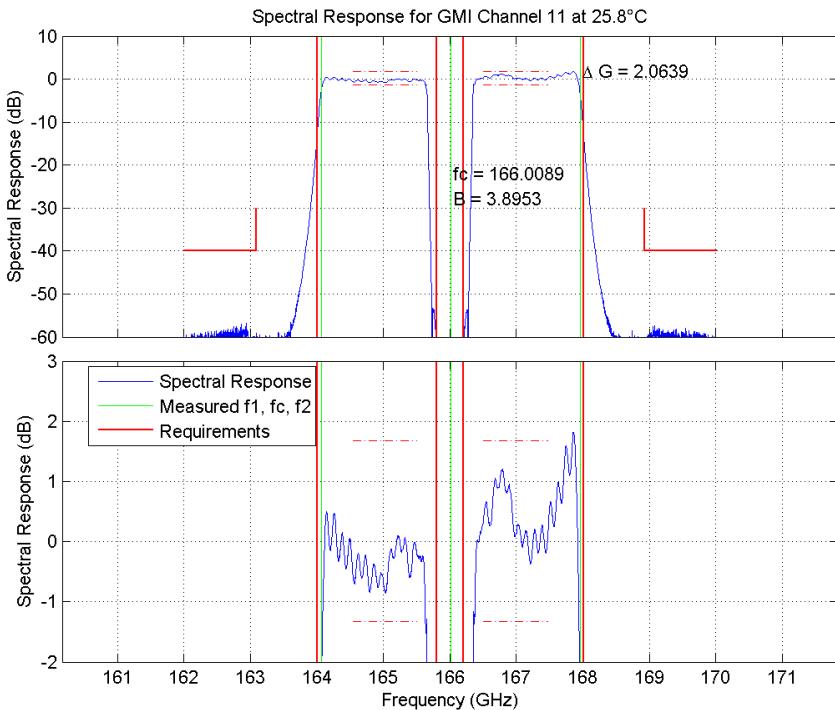


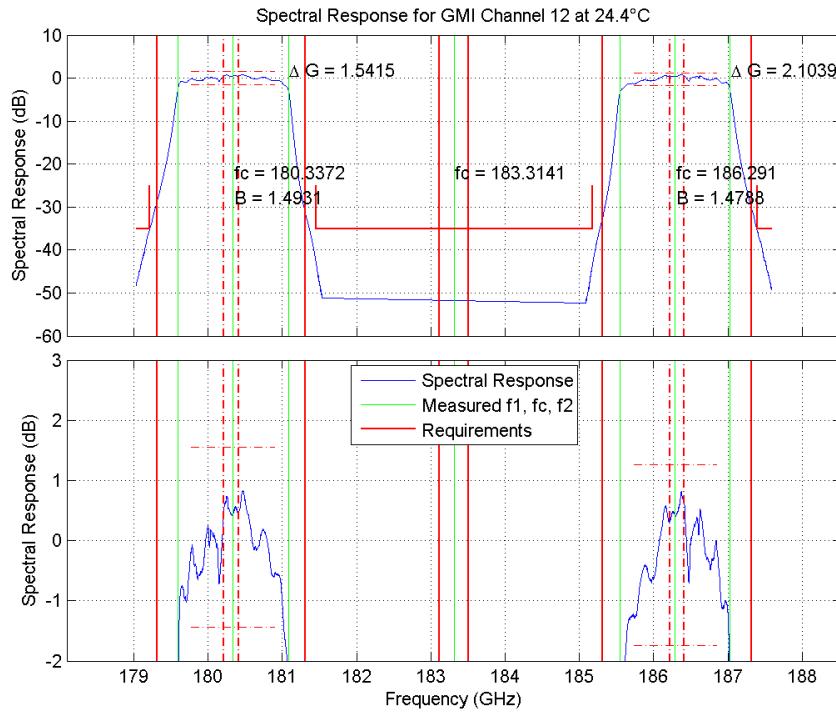
Figure1.11. Band-pass and gain variation verification data for Channel 9 at 25°C



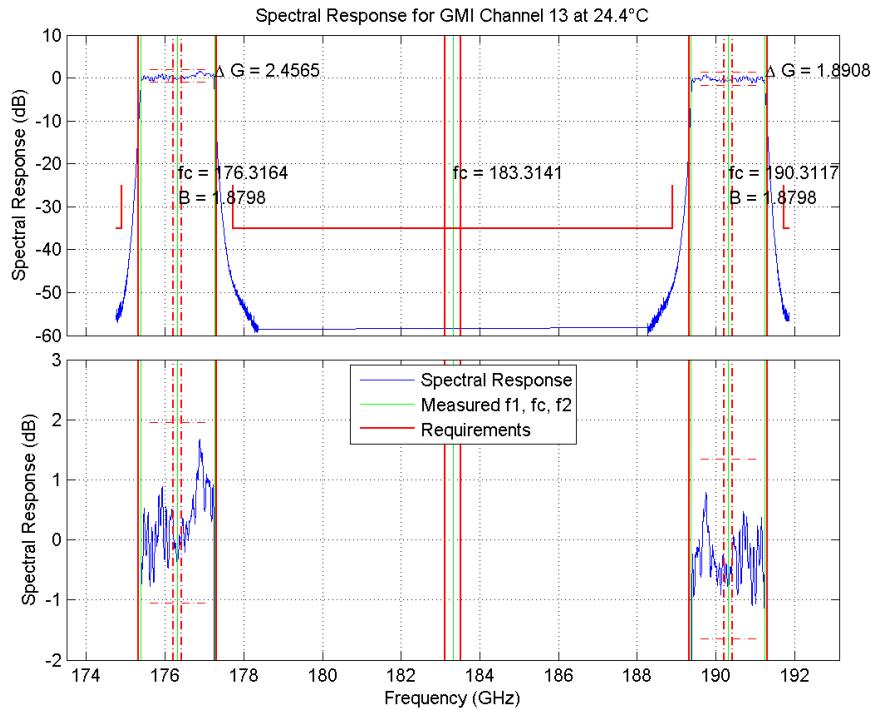
**Figure1.12.** Band-pass and gain variation verification data for Channel 10 at 25.8°C



**Figure1.13.** Band-pass and gain variation verification data for Channel 11 at 25.8°C



**Figure1.14.** Band-pass and gain variation verification data for Channel 12 at 24.4°C



**Figure1.15.** Band-pass and gain variation verification data for Channel 13 at 24.4°C

### 1.3 L1B ALGORITHM OVERVIEW

The Level 1B algorithm and software transform Level 0 counts into geolocated and calibrated antenna temperatures (Ta) and brightness temperatures (Tb). Ta is obtained by utilizing the sensor radiometric calibration as well as various corrections based on after launch analyses. Tb is derived from Ta after antenna pattern correction (APC) and along scan corrections. Figure 1.16 describes the relationship between algorithm components and products (or output).

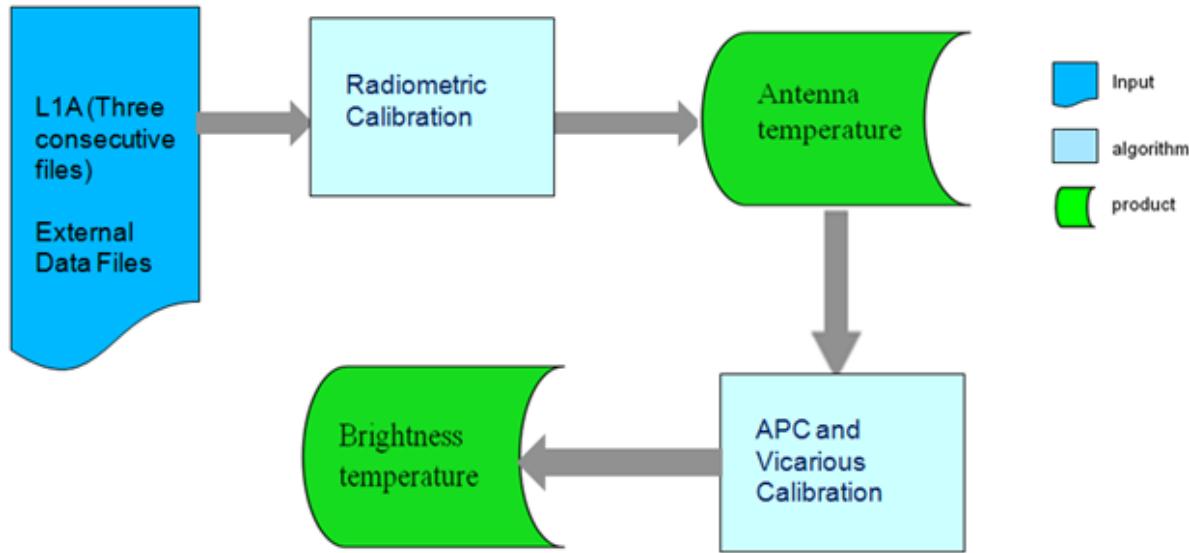


Figure 1.16. The top-level flow chart of the GMI L1B algorithm.

### 1.4 L1B DATA DESCRIPTION

The standard Level 1B GMI data are geolocated and calibrated microwave antenna temperature (Ta) and brightness temperature (Tb) in two separate data files. The base Ta data file (GMIBASE) will include all calibration parameters and measurements that are used to generate Ta and all navigation parameters that are used to “geolocate” the pixel. The base Ta data file will also include two full scan swaths:

Four geolocated swaths in GMIBASE are as follows:

1. Low-frequency swath (S1, channel 1-9, 221 pixels).
2. High-frequency swath (S2, channels 10-13, 221 pixels).
3. Full low-frequency swath (S3, maximum 500 pixels).
4. Full high-frequency swath (S4, maximum 500 pixels).

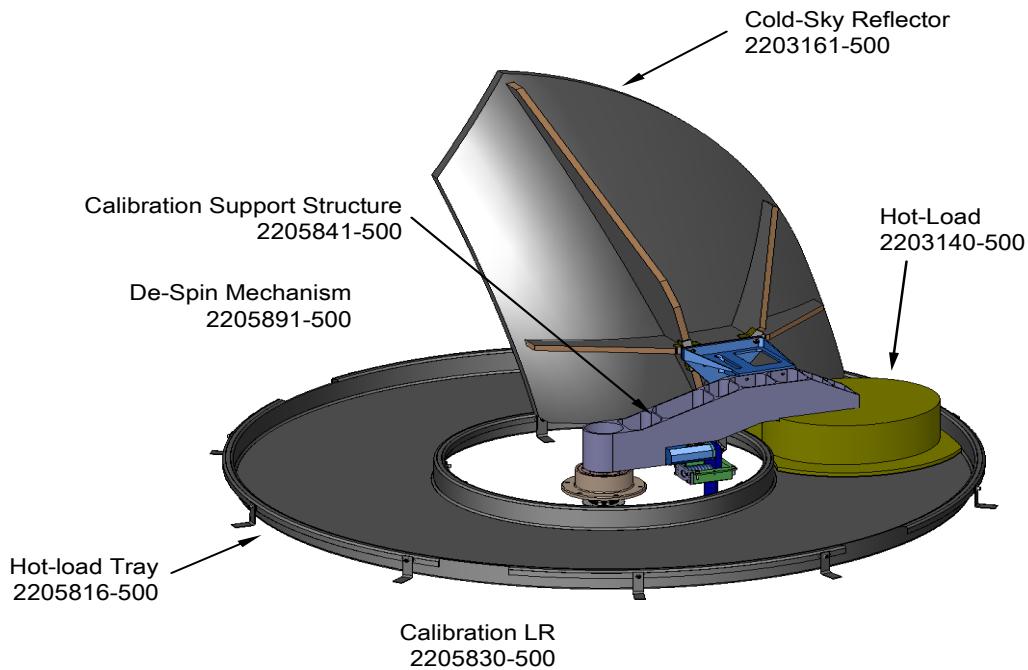
The Tb data file (1BGMI) will include all parameters for corrections of Ta. 1BGMI only has S1 and S2 swaths. Both GMIBASE and 1BGMI include sufficient information to reverse the calibration process.

Standard L1B data will be in the format of a full orbit (about 90 minutes). Realtime L1B data will be processed in a 5-minute time period.

## **2. CALIBRATION ALGORITHM**

### **2.1 RADIOMETRIC CALIBRATION**

The GMI sensor spins continuously. In each complete rotation, the sensor measures Earth radiation in a section of 140 degrees. Beyond 140 degrees up to 145 degrees, the sensor may also take valid Earth measurements if applicable. The other section of the rotation is used for calibration purposes. For channels 1-7, operational GMI has a calibration cycle that repeats every two scan rotations. In the first scan rotation, noise diodes are turned off and the cold sky and the hot load are sampled for the purpose of radiometric calibration. In the second rotation, noise diodes are turned on and the cold sky plus noise diode and hot load plus noise diode are sampled for 10-37 GHz channels. The two-scan calibration cycle provides four calibration points to calculate not only the gain and offset of the receivers, but also the excess noise temperature of the noise diodes and the nonlinearity of the receivers. For other channels (89 GHz to 183 GHz), all scans have scan by scan calibration cycle (collect hot and cold calibration data only for all scans). The calibration assembly configuration is shown in Figure 2.1. Cold sky reflector and hot load are stationary. They do not rotate with the instrument. The hot load tray mounts to the deck and rotates with the instrument.

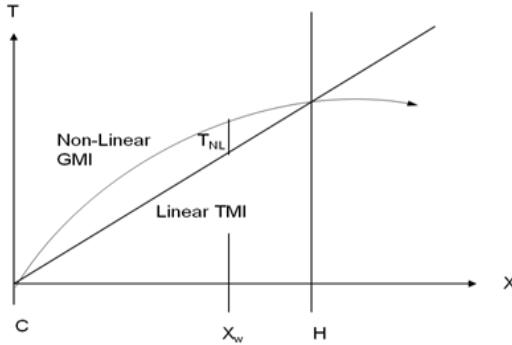


**Figure 2.1. Calibration assembly configuration; taken from BATC data book.**

The GMI uses a non-linear three-point in-flight calibration to derive antenna temperature  $T_a$ . The four-point calibration is used to monitor the sensor non-linearity and to calibrate when hot load measurements are not available for 10-36 GHz channels.

#### **2.1.1 Non-linear Radiometric Calibration**

If the transfer function is perfectly linear, two calibration points (hot and cold loads) would uniquely determine the state of the Earth observation. However, in reality, they are slightly nonlinear. Figure 2.2 shows a schematic diagram of the GMI nonlinear calibration approach as compared to the traditional linear calibration in TMI.



**Figure 2.2. Schematic diagram of GMI non-linear calibration.**

Equation 2.1 shows the GMI non-linear calibration equation for each of the 13 GMI channels. This is a quadratic radiometric transfer function.

$$T_a = X * T_h + (1-X) * T_c - 4 * T_{nl} * X * (1-X) \quad (2.1)$$

Where:

$T_a$ : antenna temperature for each pixel of the scan.

$T_h$ : mean hot load temperature of the scan;  $T_c$ : mean cold sky temperature of the scan.

$T_{nl}$ : peak non-linearity generated from look-up table or computed from four-point calibration.

$X = (C - C_c) / (C_h - C_c)$ : radiometer response.

$C$ : Earth view count of the pixel;  $C_c$ : mean cold load count;  $C_h$ : mean hot load count.

The PPS L1B algorithm uses a more conventional form (2.2) derived from the above basic equation (2.1) such that PPS will be able to trend gain, offset, and nonlinearity against the Earth view counts.

$$T_a = (b + b_{nl}) + (a + a_{nl})C + c_{nl}C^2 \quad (2.2)$$

$a = (T_h - T_c) / (C_h - C_c)$ : gain in linear equation.

$a_{nl} = -4 T_{nl} (C_h + C_c) / (C_h - C_c)^2 = -u a^2 (C_h + C_c)$ : gain due to non-linearity

$$u = 4 T_{nl} / (T_h - T_c)^2 \quad (2.3)$$

$b = (C_h T_c - C_c T_h) / (C_h - C_c)$ : offset in linear equation.

$b_{nl} = u a^2 C_h C_c$ : non-linear offset.

$c_{nl} = u a^2$ : non-linear gain.

Look-up tables of  $u$  are provided by sensor manufactory as a function of receiver gain and receiver temperature (see Appendix A). 4-point calibration also computes the  $u$  in the algorithm but output it in  $T_{nl}$  format. All these coefficients are written out in the data products such that one may easily retrieve the count back from  $T_a$ . The algorithm can switch between equation 2.2 and equation 2.1.

The nonlinearity term of equation 2.1 can be expanded as:

$$\begin{aligned} T_a^{nl} = -4*T_{nl} * X_i * (1-X_i) &= b_{nl} + a_{nl} C + c_{nl} C^2 = u a^2 (C_h C_c - (C_h + C_c)C + C^2) \\ &= u a^2 (C - C_h)(C - C_c) \end{aligned} \quad (2.4)$$

with tie points at  $C_h$  and  $C_c$  and maximum nonlinearity point at  $C = (C_h + C_c)/2$ .

For a typical 36 GHz V channel with high gain, assume  $T_c=3K$ ,  $T_h=300K$ ,  $C_c=20351$ ,  $C_h=38104$ ,  $u=-2.388E-5$ . We can derive the maximum  $u a^2 (C - C_h)(C - C_c) = 0.5266 K$  at  $C=(C_h + C_c)/2=29772$ .

The nonlinearity is also calculated on-orbit by the four-point calibration method for 10-36 GHz channels. If nonlinearity drifts a statistically significant amount, the data can be updated using on-orbit trending.

## 2.1.2 Hot Load View

The hot load consists of a non-rotating calibration target that intercepts the line-of-sight between the feed horns and the main reflector as the feed horns pass beneath the hot calibration load during each scan. The temperature of the hot load is passively controlled and will be between 240 K and 330 K over all on-orbit conditions. Figure 2.3 shows the GMI hot load calibration target. The load is sized to allow a minimum of four measurements per view for all channels. The hot load is sampled multiple times per rotation of the main reflector.

At a certain point and time, sunlight may hit the hot load and cause additional gradients that cause its effective temperature to deviate from what the PRTs read. The GMI hot load is designed to minimize such effect. However, it will still need to be analyzed during the post-launch calibration and validation.

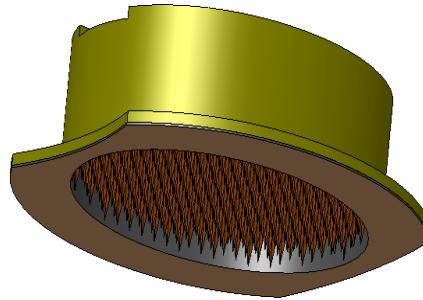


Figure 2.3. GMI hot load; taken from GMI PDR day 4-5: Calibration assembly (Randy Keller).

### Hot load temperature $T_h$ for scan $i_n$ :

The mean hot load temperature for each scan is determined by the following equations:

$$\text{Resistance of the PRT: } R_T = (C_T - C_{lo})(R_{hi} - R_{lo})/(C_{hi} - C_{lo}) + R_{lo} \quad (2.5)$$

Resistances of high calibration resistor  $R_{hi} = 2800.08$  (preliminary), and low resistor  $R_{lo} = 1500.04$  (preliminary) for the 11 PRTs.

$C_T$ ,  $C_{hi}$ ,  $C_{lo}$  are raw counts of the PRT, high-calibration resistor, and low-calibration resistor retrieved from telemetry.

**Temperature of the PRT:**  $T_T = \sum_k a(k) R_T^k$  (in  $^{\circ}\text{C}$ )  
 (2.6)

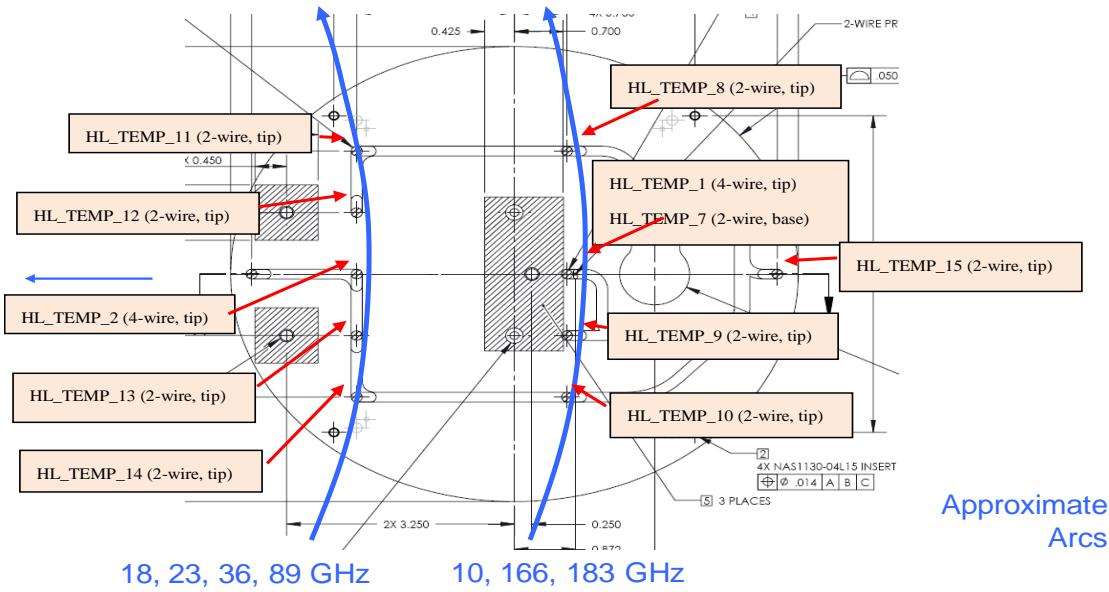
Following is a table to show typical  $C_{hi}$ ,  $C_{lo}$ , and  $a(k)$  ( $k=0,1,2,3,4,5$ ). However,  $C_{hi}$ ,  $C_{lo}$  are actually read from telemetry for each scan and may deviate from their typical values.

**Table 2.1. PRT temperature coefficients.**

PRT#	$C_{hi}$	$C_{lo}$	$a(0)$	$a(1)$	$a(2)$	$a(3)$	$a(4)$	$a(5)$
HL1	45201.6	10033.94	-260.3268548	0.162461012	-4.58202E-05	2.52991E-08	-6.611E-12	6.92314E-16
HL2	45201.6	10033.94	-256.6634276	0.153105919	-3.64844E-05	2.06898E-08	-5.48131E-12	5.82286E-16
HL7	45201.6	10033.94	-229.1336105	0.081543673	3.70996E-05	-1.71872E-08	4.26292E-12	-4.19728E-16
HL8	45201.6	10033.94	-239.1461698	0.10633824	1.27543E-05	-5.16554E-09	1.28903E-12	-1.24749E-16
HL9	45201.6	10033.94	-265.1250734	0.172522043	-5.44843E-05	2.87902E-08	-7.24365E-12	7.28819E-16
HL10	45201.6	10033.94	-227.5221504	0.080916951	3.41126E-05	-1.36997E-08	2.84902E-12	-2.20101E-16
HL11	45201.6	10033.94	-173.9211332	-0.056511813	0.000174168	-8.47823E-08	2.08193E-11	-2.03058E-15
HL12	45201.6	10033.94	-220.8544276	0.062438765	5.3899E-05	-2.41548E-08	5.58068E-12	-5.02863E-16
HL13	45201.6	10033.94	-231.8990945	0.08994359	2.70811E-05	-1.12182E-08	2.51066E-12	-2.1678E-16
HL14	45201.6	10033.94	-247.547878	0.127616967	-8.95689E-06	5.78887E-09	-1.44903E-12	1.46345E-16
HL15	45201.6	10033.94	-241.1117667	0.113170615	3.50976E-06	6.80404E-10	-4.94577E-13	8.72336E-17

### Scan average and tray correction:

Scan hot load temperature  $T_{Tave}$  (i),  $i=1,2$ , is split into two categories.  $T_{Tave}$  (1) is averaged over PRT #1 and #8-10 for the use of 10, 166, 183 GHz channels.  $T_{Tave}$  (2) is averaged over PRT #2 and #11-14 for the use of 18, 23, 36, 89 GHz channels. PRT #7 (base) and PRT #15 are not used in calibration. Figure 2.4 demonstrates the geometry of hot load.



**Figure 2.4. GMI hot load geometry.**

### Correction using hot load tray temperature:

$$T_{hscan}(i) = w_0 + w_1 T_{Tave}(i) + u_0 + u_1(T_{Ttray} - T_{Tave}(i)) + u_2(T_{Ttray} - T_{Tave}(i))^2 + u_3(T_{Ttray} - T_{Tave}(i))^3 \quad (2.7)$$

b(j), w<sub>0</sub>, w<sub>1</sub>, u<sub>0</sub>, u<sub>1</sub>, u<sub>2</sub>, u<sub>3</sub> for all channels are summarized in Table 2.2 (revised).

**Table 2.2. Cubic correction coefficients for hot load temperatures.**

Frequency (GHz)	pol	w0	w1	u0	u1	u2	u3
10.65	Vpol	0.000	1.000	0.006	0.001842	8.64057E-06	1.43994E-08
10.65	Hpol	0.000	1.000	0.006	0.001842	8.64057E-06	1.43994E-08
18.7	Vpol	0.000	1.000	0.034	0.005192	2.55512E-05	4.56092E-08
18.7	Hpol	0.000	1.000	0.034	0.005192	2.55512E-05	4.56092E-08
23.8	Vpol	0.000	1.000	0.039	0.006980	3.41741E-05	6.07519E-08
36.64	Vpol	0.000	1.000	0.061	0.007250	3.50306E-05	5.9566E-08
36.64	Hpol	0.000	1.000	0.061	0.007250	3.50306E-05	5.9566E-08
89	Vpol	0.000	1.000	0.078	0.009411	4.39606E-05	6.89555E-08
89	Hpol	0.000	1.000	0.078	0.009411	4.39606E-05	6.89555E-08
166	Vpol	0.000	1.000	0.055	0.008895	4.30404E-05	7.46213E-08
166	Hpol	0.000	1.000	0.055	0.008895	4.30404E-05	7.46213E-08
183.3 ±3	Vpol	0.000	1.000	0.055	0.008895	4.30404E-05	7.46213E-08
183.3 ±7	Vpol	0.000	1.000	0.055	0.008895	4.30404E-05	7.46213E-08

**T<sub>Ttray</sub>**

$$R'_T = (C'_T - C'_{lo})(R'_{hi} - R'_{lo})/(C'_{hi} - C'_{lo}) + R'_{lo} \quad (2.8)$$

Resistances of high calibration resistor R'<sub>hi</sub> = 3157 (preliminary), and low resistor R'<sub>lo</sub> = 1195 (preliminary) for the tray.

C'<sub>T</sub>, C'<sub>hi</sub>, C'<sub>lo</sub> are raw counts of the tray, high-calibration resistor, and low-calibration resistor retrieved from telemetry.

$$\text{Temperature of the tray: } T_T = \sum_k a(k) R'^k_T \quad (\text{in } ^\circ\text{C}) \quad (2.9)$$

Following is a table to show typical C'<sub>hi</sub>, C'<sub>lo</sub>, and a(k) (k=0,1,2,3,4,5). C'<sub>hi</sub>, C'<sub>lo</sub> are read from telemetry.

**Table 2.3. Tray temperature coefficients.**

C' <sub>hi</sub>	C' <sub>lo</sub>	a(0)	a(1)	a(2)	a(3)	a(4)	a(5)
58170.308	7706.137	-238.3771643	0.108516065	7.18387E-06	-1.12508E-09	8.5039E-14	2.92338E-18

### Average over multi-scans:

Since the hot load counts are multi-scan averaged, it is preferable that the hot load temperature is averaged over the same number of scans.

$$T_h = \sum_i k(i) T_{hscan}(i) / \sum_i k(i)$$

T<sub>h</sub> are averaged over 16 scans for channels 1-4, index scan -7 to +8 scans, over 14 scans for channel 5, index scan -6 to +7 scans, over 12 scans for channels 6-7, index scan -5 to +6 scans, over 5 scans for channels 8-13, index scan and ±2 scans.

**Hot load count for scan i<sub>n</sub>** is determined by equation (2.10).

The hot load counts are corrected for errors induced by earth magnetic field before they are processed for calibration (see Section 2.4).

$$C_h = (\sum_i \sum_j k(i,j) C_{hot}(i,j)) / \sum_i \sum_j k(i,j) \quad (2.10)$$

$j=1,2,3, \dots n_{hot}$ .  $n_{hot}$  is the number of hot samples of each scan for each channel.

$i = i_n - N_h, i_n - N_h + 1, i_n - N_h + 2, \dots, i_n + N_h$ .  $i_n$  is the scan number of the granule to be calibrated and  $2N_h + 1$  is the number of scans within the screen window.

The hot load sampling tables are shown as follows. However, the best table is used in the code.

**Table 2.4. Hot load sampling.**

Frequency	Nominal Sample Table		Spare1 Sample Table		Best Samples to Use (Revised by or-orbit data)	
	Hot Start	Hot End	Hot Start	Hot End	Hot Start	Hot End
10 GHz	272	282	269	285	273	283
18 GHz	306	316	303	319	307	317
23 GHz	306	316	303	319	306	318
36 GHz	352	366	349	369	352	367
89 GHz	327	346	324	349	325	347
166 GHz	315	339	312	342	320	335
183 GHz	329	353	326	356	330	350

Collect data when the noise diode is off.

For channels 1-4,  $C_h$  are averaged over 8 scans. If the diode is off for the index scan  $i_n$  (index scan):  $i_n, i_n \pm 2, i_n \pm 4, i_n \pm 6, i_n + 8$ . If the diode is on for the index scan:  $i_n \pm 1, i_n \pm 3, i_n \pm 5, i_n \pm 7$ . For channel 5,  $C_h$  are averaged over 7 scans. If the diode is off for the index scan  $i_n$  (index scan):  $i_n, i_n \pm 2, i_n \pm 4, i_n \pm 6$ . if the diode is on for the index scan:  $i_n \pm 1, i_n \pm 3, i_n \pm 5, i_n + 7$ . For channels 6-7,  $C_h$  are averaged over 6 scans. If the diode is off for the index scan  $i_n$  (index scan):  $i_n, i_n \pm 2, i_n \pm 4, i_n + 6$ . If the diode is on for the index scan:  $i_n \pm 1, i_n \pm 3, i_n \pm 5$ . For channels 8-13,  $C_h$  is always averaged over five scans:  $i_n, i_n \pm 1, i_n \pm 2$ .

#### **Hot load + Noise Diode Counts for scan $i_n$ :**

The Hot Load + Noise Diode counts are corrected for errors induced by earth magnetic field before they are processed for calibration (see Section 2.4).

$$C_{hn} = (\sum_i \sum_j k(i,j) C_{hot+diode}(i,j)) / \sum_i \sum_j k(i,j) \quad (2.11)$$

Collect data when the noise diode is on.

For channels 1-4,  $C_{hn}$  are averaged over 8 scans. If the diode is on for the index scan  $i_n$  (index scan):  $i_n, i_n \pm 2, i_n \pm 4, i_n \pm 6, i_n + 8$ . If the diode is off for the index scan:  $i_n \pm 1, i_n \pm 3, i_n \pm 5, i_n \pm 7$ . For channel 5,  $C_{hn}$  are averaged over 7 scans. If the diode is on for the index scan  $i_n$  (index scan):  $i_n, i_n \pm 2, i_n \pm 4, i_n \pm 6$ . If the diode is off for the index scan:  $i_n \pm 1, i_n \pm 3, i_n \pm 5, i_n + 7$ . For channels 6-7,  $C_{hn}$  are averaged over 6 scans. If the diode is on for the index scan  $i_n$  (index scan):  $i_n, i_n \pm 2, i_n \pm 4, i_n + 6$ . If the diode is off for the index scan:  $i_n \pm 1, i_n \pm 3, i_n \pm 5$ .

#### **Bad-case handling:**

The mean and variance of hot load counts and hot load + noise diode counts are computed for each granule. The algorithm takes mean  $\pm 3$  sigma (6 sigma if variance is small) as valid values.

If certain scans are missing or invalid, the algorithm will continue to the next scan until the number of scans to be averaged is equal to the number described above for all channels. However, the maximum number of scans to be searched is 20. If there is no valid hot load information within  $\pm 10$  scans, the algorithm will perform linear interpolation using the closest scans before and after the index scan and set the calibration quality flag to non-zero (0 indicates good calibration). If there is no hot load information within 200 scans, the algorithm will either use the hot load backup algorithm if cold sky measurements are available, or else generate missing Ta/Tb data for this scan.

### **2.1.3 Cold Sky View**

The cold calibration point is provided by the cold sky reflector (CSR), which allows the feed horns to view targets with a temperature of approximately 2.7 K. The cold sky view is also sampled multiple times per rotation of the main reflector and over multiple rotations of the main reflector. Table 2.5 shows mean cold sky temperature  $T_c$  for all GMI channels.

**Table 2.5. Mean cold sky temperature  $T_c$  for all GMI channels.**

Frequency (GHz)	10.65	18.7	23.8	36.64	89.0	166.0	183.31
Cold Load Temperature	2.74	2.75	2.77	2.82	3.27	4.43	4.76

#### **Cold load counts for scan $i_n$ :**

The cold load counts are corrected for errors induced by earth magnetic field before they are processed for calibration (see Section 2.4).

The mean cold sky count is determined by equation (2.12)

$$C_c = (\sum_i \sum_j k(i,j) C_{\text{cold}}(i,j)) / \sum_i \sum_j k(i,j) \quad (2.12)$$

$j=1,2,3, \dots n_{\text{cold}}$ .  $n_{\text{cold}}$  is the number of cold samples of each scan for each channel.

$i = i_n - N_h, i_n - N_h + 1, i_n - N_h + 2, \dots, i_n + N_h$ .  $i_n$  is the scan number of the current scan to be calibrated and  $2N_h + 1$  is the number of scans within the screen window. Collect data when the noise diode is off.

The cold load sampling tables are shown as follows. However, the best table is used in the code.

**Table 2.6. Cold sky sampling.**

Frequency	Nominal Sample Table		Spare1 Sample Table		Best Samples to Use*	
	Cold Start	Cold End	Cold Start	Cold End	Cold Start	Cold End
10 GHz	340	353	337	356	342	368
18 GHz	368	393	365	396	390	410
23 GHz	368	393	365	396	388	408
36 GHz	418	459	415	462	437	460
89 GHz	392	433	389	436	410	440
166 GHz	381	422	378	425	392	442
183 GHz	395	436	392	439	398	452

Collect data when the noise diode is off.

For channels 1-7,  $C_c$  is averaged over 5 scans. If the diode is off for the index scan  $i_n$  (index scan):  $i_n, i_n \pm 2, i_n \pm 4$ . If the diode is on for the index scan:  $i_n \pm 1, i_n \pm 3, i_n \pm 5$ . For channels 8-13,  $C_c$  is averaged over five scans:  $i_n, i_n \pm 1, i_n \pm 2$ .

#### **Cold load + noise diode counts for scan $i_n$ :**

$$C_{cn} = (\sum_i \sum_j k(i,j) C_{cold+diode}(i,j)) / \sum_i \sum_j k(i,j) \quad (2.13)$$

The Cold Load + Noise Diode counts are corrected for errors induced by earth magnetic field before they are processed for calibration (see Section 2.4).

Collect data when the noise diode is on.

For channels 1-7,  $C_{cn}$  are averaged over 5 scans. If the diode is on for the index scan  $i_n$  (index scan):  $i_n, i_n \pm 2, i_n \pm 4$ . If the diode is off for the index scan:  $i_n \pm 1, i_n \pm 3, i_n \pm 5$ .

#### **Bad-case handling:**

The cold sky view is a more complex combination of sources than the hot load. Contributions other than from cold space come from reflections and emission from the instrument. There is also Earth view intrusion into the cold sky view primarily through the back lobe of the CSR. The back lobe looks at the main reflector, which sees the Earth. The CSR is tilted up at a sufficient angle that little contamination comes from the Earth directly.

Due to the orbital and cold sky view geometry, the Moon may intrude into the cold sky view. This lunar intrusion has been clearly observed by many other satellite microwave radiometers that employ cold sky calibration (SSMI, SSMI/S, TMI, AMSR, and WindSat). The calibration algorithm will remove as much as possible of the contaminations of the cold sky view.

The mean and variance of cold sky counts and cold sky + noise diode counts are computed for each granule (if Moon index is set, the value will be excluded to compute mean and variance). The algorithm takes mean  $\pm 3$  sigma (6 sigma if variance is small) as valid values. If certain scans are missing or invalid, the algorithm will continue to next scan until the number of scans to be averaged is equal to the numbers described above for all channels.

However, the maximum number of scans to be searched is 20. If there is no valid cold load information within  $\pm 10$  scans, the algorithm will perform linear interpolation using the closest scans before and after the index scan and set the calibration quality flag to non-zero (0 indicates good calibration). If there is no cold load information within 400 scans, the algorithm will generate missing Ta/Tb data for this scan.

#### **2.1.4 Nonlinearity**

Nonlinearity is determined by receiver gain and receiver temperature. Receiver gain is read from telemetry and determined by the following table:

**Table 2.7. Receiver gain settings**

Channels	low gain	normal gain	high gain
10 GHz	6	4	2
18 GHz	6	4	2
23 GHz	6	4	2
36 GHz	6	4	2
89 GHz	6	4	2
166 GHz	4	2	1
183 GHz	5	4	3

Receiver temperatures are retrieved using a similar way of retrieving tray temperature.

$$\text{Resistance of the receiver: } R'_T = (C'_T - C'_{lo}) / (C'_{hi} - C'_{lo}) + R'_{lo} \quad (2.14)$$

Resistances of high calibration resistor  $R'_{hi} = 3157$  (preliminary), and low resistor  $R'_{lo} = 1195$  (preliminary) for the tray.

$C'_T$ ,  $C'_{hi}$ ,  $C'_{lo}$  are raw counts of the tray, high-calibration resistor, and low-calibration resistor retrieved from telemetry.

$$\text{Temperature of the receiver: } T_{\text{receiver}} = \sum_k a(k) R'_T \text{ (in } ^\circ\text{C)} \quad (2.15)$$

Following is a table to show typical  $C'_{hi}$ ,  $C'_{lo}$ , and  $a(k)$  ( $k=0,1,2,3,4,5$ ).  $C'_{hi}$ ,  $C'_{lo}$  are read from telemetry.

**Table 2.8. Receiver temperature polynomial coefficients.**

Freq	$C'_{hi}$	$C'_{lo}$	$a(0)$	$a(1)$	$a(2)$	$a(3)$	$a(4)$	$a(5)$
10GHz	58170.308	7706.137	-235.8509438	0.099626991	1.74703E-05	-6.44468E-09	1.37026E-12	-1.1467E-16
18GHz	58170.308	7706.137	-236.0646535	0.100765016	1.63998E-05	-6.02941E-09	1.29013E-12	-1.08618E-16
36GHz	58170.308	7706.137	-236.2001883	0.100808265	1.64408E-05	-6.03744E-09	1.29008E-12	-1.08434E-16
36GHz	58170.308	7706.137	-236.0667138	0.100417622	1.67243E-05	-6.14661E-09	1.31071E-12	-1.09965E-16
89GHz	58170.308	7706.137	-236.1859287	0.100662332	1.65911E-05	-6.10118E-09	1.30393E-12	-1.09648E-16
166GHz	58170.308	7706.137	-236.2362645	0.100930691	1.63367E-05	-6.00249E-09	1.28482E-12	-1.08198E-16
183GHz	58170.308	7706.137	-236.1070635	0.100466029	1.67138E-05	-6.13536E-09	1.30677E-12	-1.09468E-16

Look-up tables of  $\mathbf{u}$  are provided by sensor manufactory as a function of receiver gain and receiver temperature (see Appendix A) for all channels.  $\mathbf{u}$  is also computed from the four-point algorithm for trending and comparisons.

## 2.1.5 Moon and RFI Corrections

### Moon Correction:

The geolocation tool computes the Moon vector  $\mathbf{V}_{\text{moon}}$  each scan in GMI coordinate system (GICS). The algorithm computes the angle ( $\theta$ ) between Moon vector and cold beam pointing vectors  $\mathbf{V}_{\text{cold}}$  in the GICS for all cold view samples.

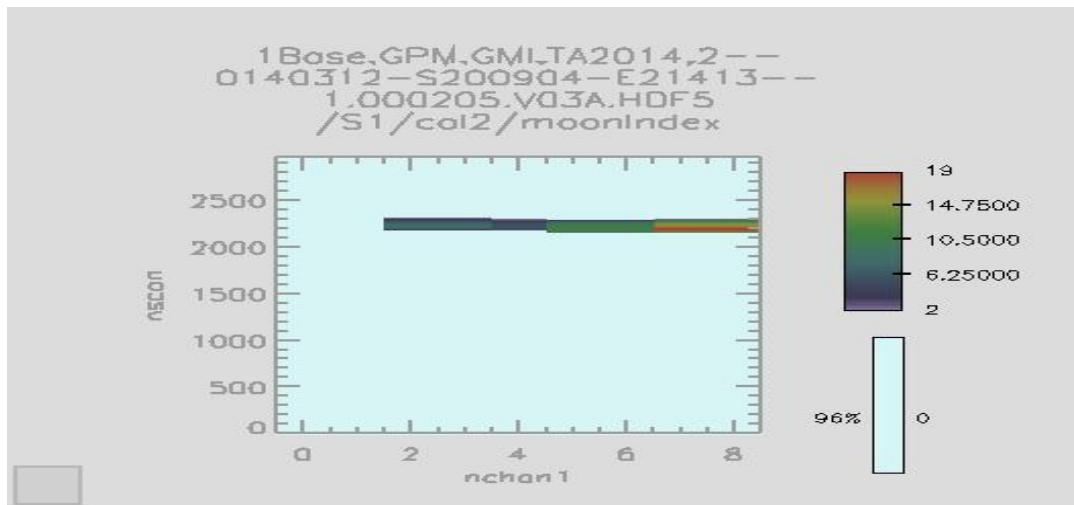
$$\cos\theta = \mathbf{V}_{\text{moon}} \cdot \mathbf{V}_{\text{cold}} / (|\mathbf{V}_{\text{moon}}| |\mathbf{V}_{\text{cold}}|) \quad (2.16)$$

$$= [ \mathbf{V}_{\text{moon}}(\mathbf{x}) \cdot \mathbf{V}_{\text{cold}}(\mathbf{x}) + \mathbf{V}_{\text{moon}}(\mathbf{y}) \cdot \mathbf{V}_{\text{cold}}(\mathbf{y}) + \mathbf{V}_{\text{moon}}(\mathbf{z}) \cdot \mathbf{V}_{\text{cold}}(\mathbf{z}) ] / \{ [ (\mathbf{V}_{\text{moon}}(\mathbf{x})^2 + \mathbf{V}_{\text{moon}}(\mathbf{y})^2 + \mathbf{V}_{\text{moon}}(\mathbf{z})^2)^{1/2} ] [ (\mathbf{V}_{\text{cold}}(\mathbf{x})^2 + \mathbf{V}_{\text{cold}}(\mathbf{y})^2 + \mathbf{V}_{\text{cold}}(\mathbf{z})^2)^{1/2} ] \}$$

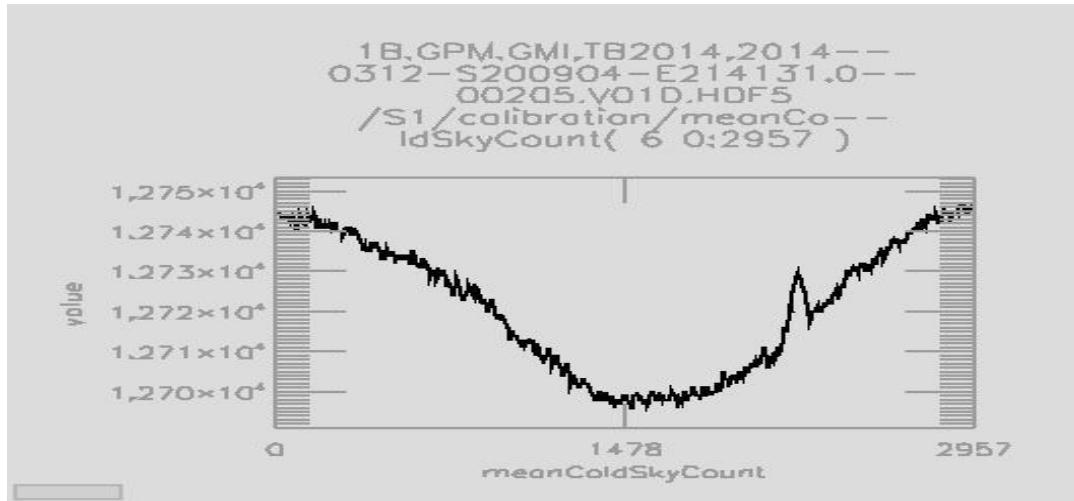
If  $\theta < 6$  degrees, the algorithm sets the Moon index to non-zero and the cold sample is excluded for calibration. If the Moon index is set for a large section of the swath ( $> 20$  scans), the algorithm will use valid scans before and after the event to perform linear interpolation.

Appendix B provides the look-up tables of cold beam pointing vectors (revised).

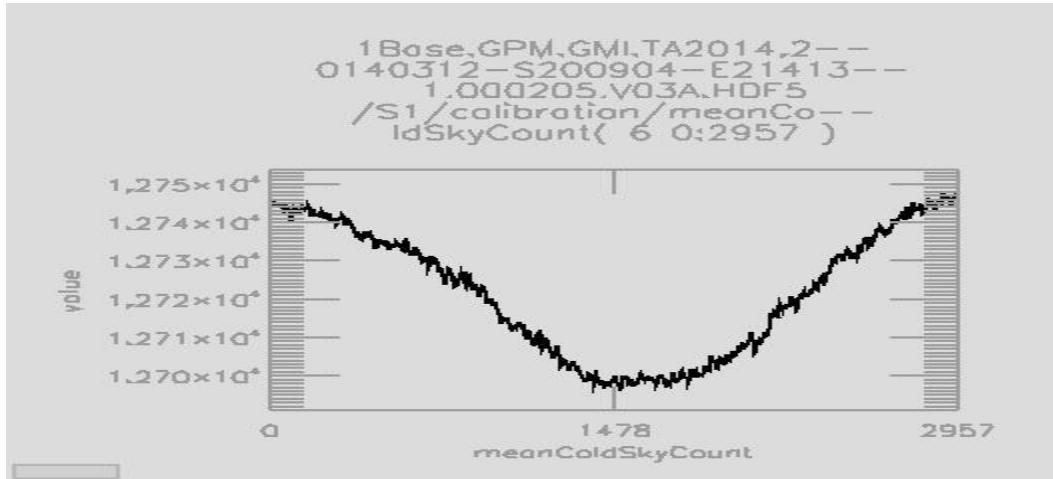
Following figures show an example of moon flags, scan averaged cold counts before correction and after correction. Figure 2.5 is the index from production for low frequency swath channels. The value of index is the number of cold samples contaminated by the moon light. The intrusion occurred around scans 2200 to scans 2400 for 18, 23, 36, and 89 GHz channels. Figure 2.6 show the spikes of mean cold counts around this area before corrections. Figure 2.7 is the results from the current version and the spikes due to moon intrusion are removed.



**Figure 2.5. Moon flags for S1, indicates moon intrusions onto 18 GHz to 89 GHz channels**



**Figure 2.6. Scan cold counts of 36 GHz H channel with no moon correction in V01D data**



**Figure 2.7.** Scan cold counts of 36 GHz H channel with moon correction in V03A data.

### RFI Correction:

There are two RFI flagging methods in the algorithm. One is a simple limit check based on minimum cold count of the scan assuming that the intrusion is only to part of the cold sample sections. If the whole scan is contaminated, the scan is labeled as bad calibration and will be handled by bad-case handling described in Section 2.1.3.

The simple limit check method first determines the lowest value from all cold samples of a scan. The code then computes the maximum cold count value derived from the following table:

**Table 2.9. Maximum Gradients of Cold Counts within Each Scan**

Channels:	1	2	3	4	5	6	7	8	9	10	11	12	13
Cold Offset	130	122	118	132	78	78	78	78	198	198	198	198	198
Cold + NoiseD Offset	240	232	202	198	122	116	112						

Maximum value = Lowest value + offset. If a cold sample within this scan is larger than the Maximum value, it will be flagged (to non-zero). This method tends to under flag the RFI cold samples by about 20%.

The other method is based on the iterative mean comparison / dilation method. The method is quite complicated and has the following steps:

Step 1: Scan Averaging – create a scan average, ignoring data that has been already flagged. On the first iteration, all data will be included. First, the data are averaged over the cold samples within each scan; then, multiple scans are averaged together. For channels with noise diodes, this is done separately for the cold and cold+noise scans. In this version, 3 effective scans are used for all channels.

Step 2: Removal of scan average – For each sample within the each scan, the scan average from step 1 is removed.

Step 3: Cold swath flattening – This is done for each along-scan cell position by taking the median across all scans of the orbit. The computed variation is then subtracted from the result of step 2. This step provides additional sensitivity by removing scan-repeating variations.

Step 4: Thresholding – All cold samples from the result of step 3 are compared to a pre-determined threshold for each channel and noise diode state (Table 2.10). Data exceeding the threshold or that have been flagged on a previous iteration are flagged.

Step 5: Robust Dilation – This step widens and fills in the flagged region. For each cell if at least  $k$  cells in the surrounding  $m \times n$  region are flagged, then that cell is additionally flagged. If less than  $k$  cells are flagged, then the cell is set to unflagged. This method will unflag spurious noise measurements allowing the user to set the thresholds in step 4 below 3-sigma, providing higher sensitivity.

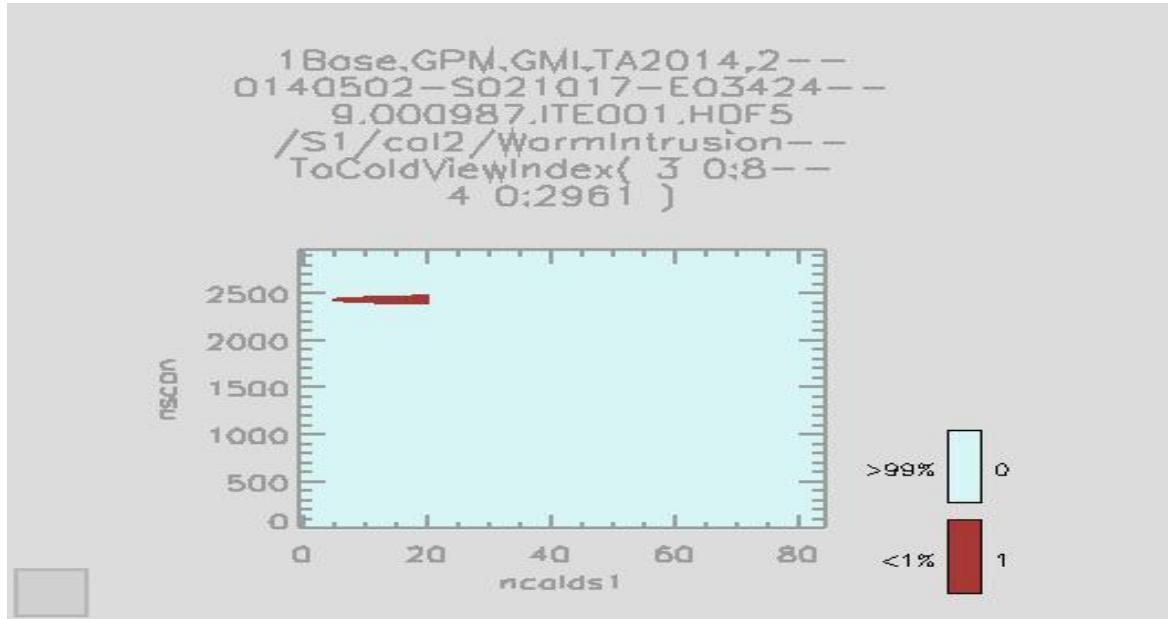
Step 6: Iterate – Repeat steps 1-5 for a specified number of iterations.

**Table 2.10. Cold Counts Threshold of Second RFI Flagging Method**

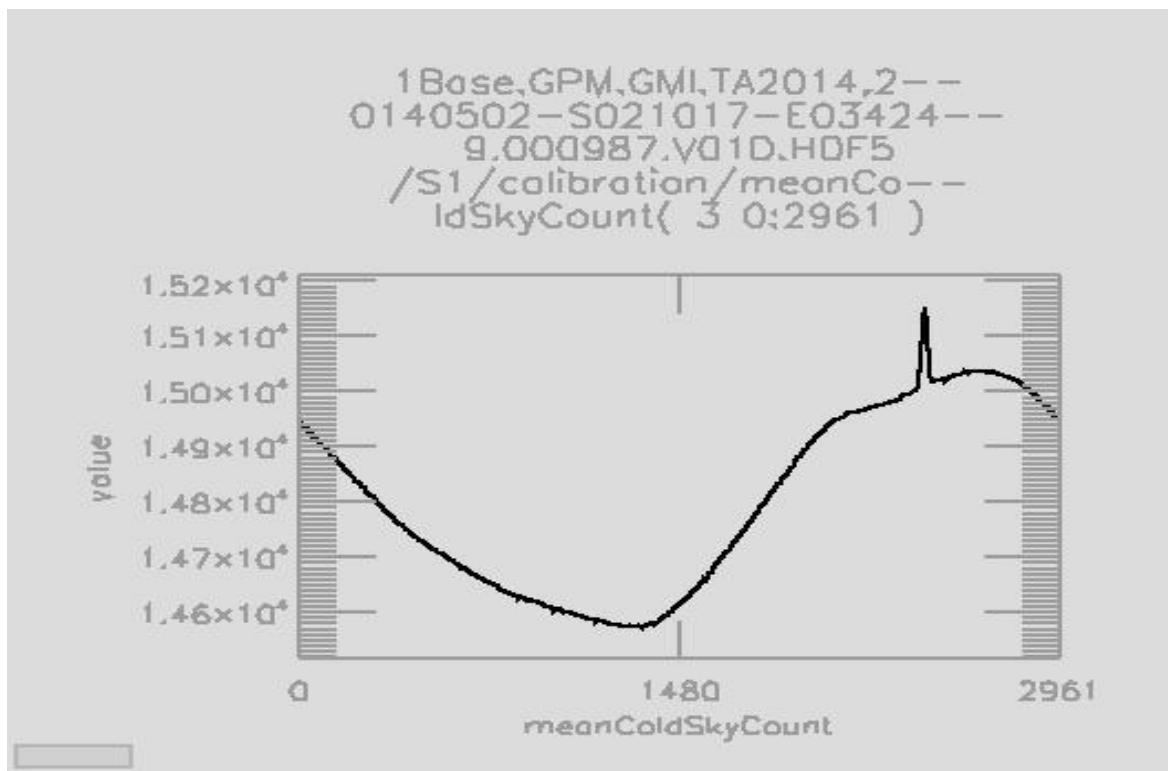
Channel	Cold count threshold	Cold+noise count threshold	Cold scan average scans	Number of Iterations	Dilation window ( $m_{\text{samp}} \times n_{\text{scan}}$ )	Dilation number of samples threshold ( $k$ )
10V	24.0	62.0	3	3	3 x 15	5
10H	24.7	62.0	3	3	3 x 15	5
18V	27.3	57.4	3	6	3 x 15	5
18H	25.0	55.1	3	6	3 x 15	5
23V	23.9	40.0	3	3	3 x 15	5
36V	22.9	36.8	3	3	3 x 15	5
36H	22.9	36.3	3	3	3 x 15	5
89V	22.6		3	3	3 x 15	5
89H	21.0		3	3	3 x 15	5
166V	56.8		3	3	3 x 15	5
166H	55.1		3	3	3 x 15	5
183VA	54.5		3	3	3 x 15	5
183VB	49.0		3	3	3 x 15	5

The second method with the chosen thresholds tends to over flag the cold sample about 20-30%. The algorithm actually uses both flagging methods to determine the final flagging value of a cold sample. If a sample is flagged (to non-zero) by the first method, the sample is flagged as RFI sample. If a sample is flagged by the second method but not by the first method, the code search a window of 15 samples by 61 scans to see if any of the cold samples in the window is flagged by the first method. If one or more cold samples within the window are flagged by the first method, the sample is flagged, otherwise, the sample is not flagged. If a cold sample is flagged, the sample is excluded in calibration.

Following figures show the results before and after the correction. Figure 2.8 is the index from production for 18 GHz H channel. The total cold sample number is 21 for this channel. The intrusion occurred around scans 2400 to scans 2500. Figure 2.9 show the spikes of mean cold counts around this area before corrections. Figure 2.10 is the results from the current version and the spikes due to warm RFI intrusion are removed.



**Figure 2.8.** Cold samples that are flagged as warm intrusions for 18 GHz H channel.



**Figure 2.9.** Scan cold counts of 18 GHz H channel with no correction in V01D data.

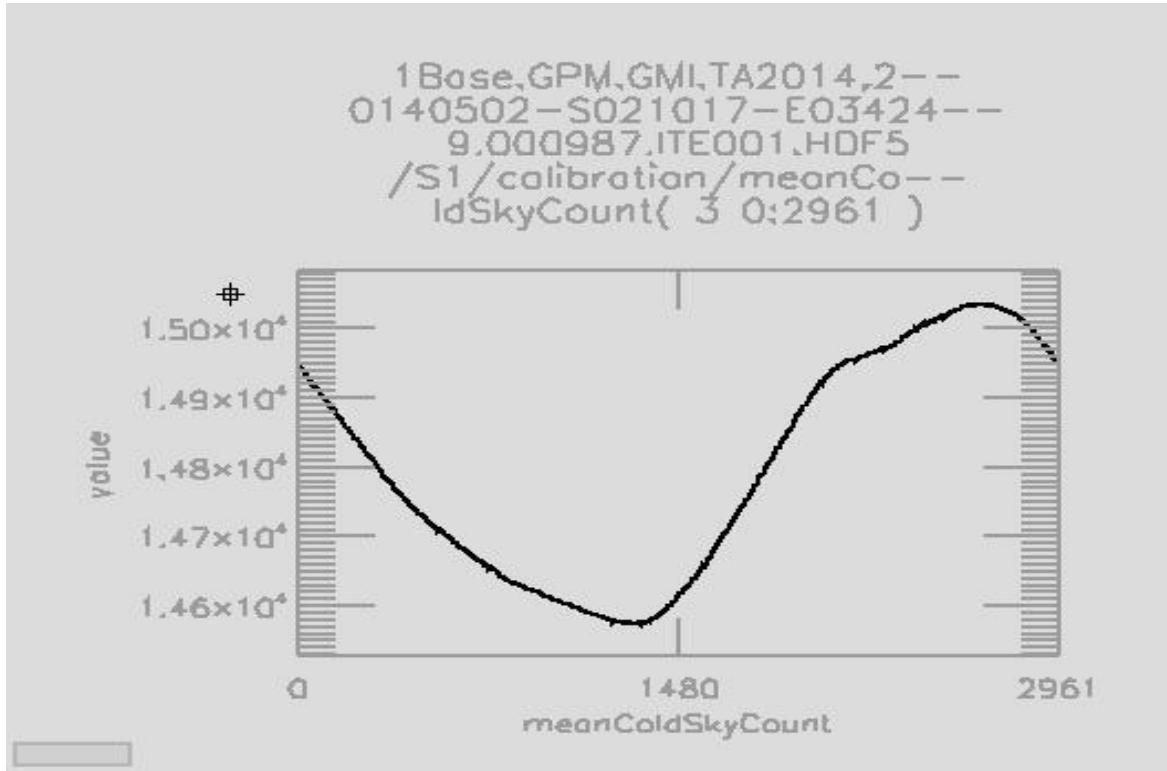
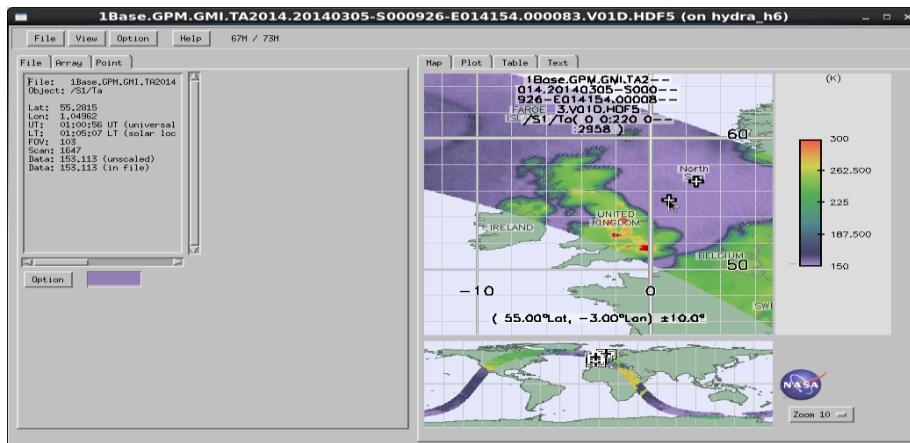
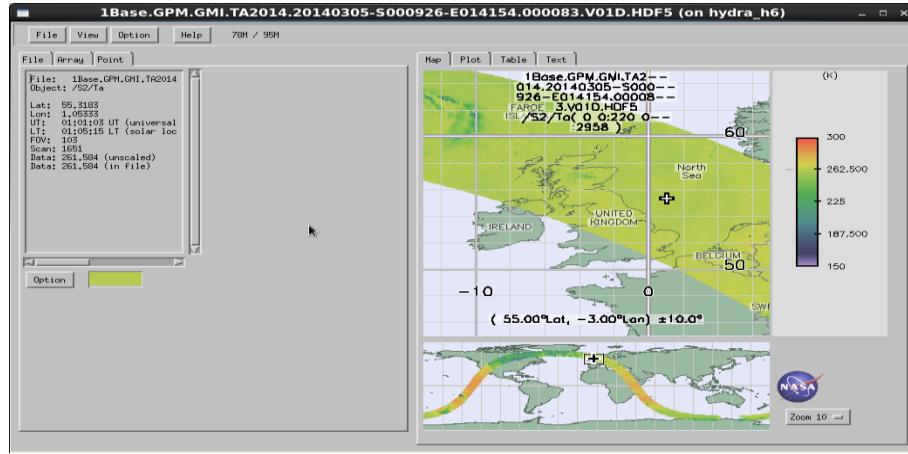


Figure 2.10. Scan cold counts of 18 GHz H channel with RFI correction in ITE001 data.

## 2.1.6 Earth View

A forward section about  $145^\circ$  is used to view the Earth targets. The normal data have 221 samples for each scan. However, in cases when the data beyond  $140^\circ$  are useful, one scan may have more than 221 pixels. The data beyond the normal earth view range can be retrieved from GMIBASE full rotation antenna temperatures. Due to the difference of incidence angles between lower frequency (channels 1-9) and high-frequency (channels 10-13) channels, the swath widths, as well as the geolocations of the two groups, are different. Figure 2.5 shows antenna temperatures of 10 GHz V (low frequency swath) and 166 GHz V (high frequency swath) channels.



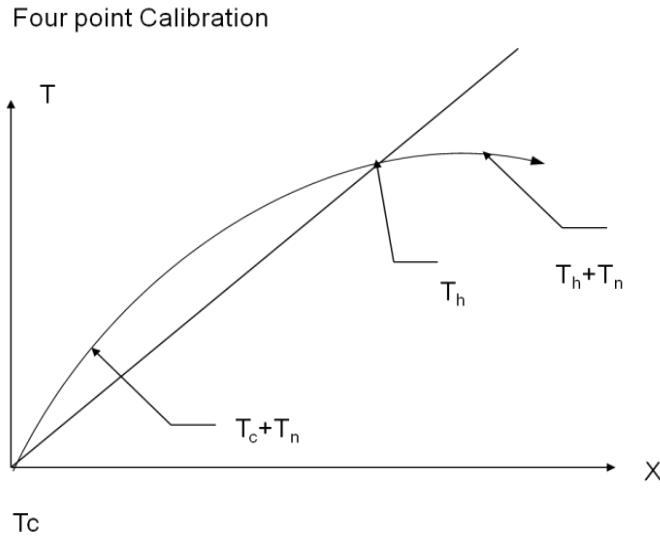


**Figure 2.11. Sample GMI 10 GHz V channel Ta (upper) and 166 GHz V channel Ta (lower).**

There are RFI to the earth view samples (For example: Figure 2.11 upper panel in England). Currently, the code flags earth view pixels if Tb is greater than 325 K for all channels. The earth view counts are corrected for errors induced by earth magnetic field before they are used to derive antenna temperature Ta (see Section 2.4).

### 2.1.7 Noise Diodes and Four-Point Calibration

The noise diodes are implemented for channels 1-7. These noise diodes are turned on every other scan such that additional calibration measurements were taken to perform four-point calibration to determine sensor nonlinearity. Figure 2.6 is the schematic diagram of four-point calibration.



**Figure 2.12. Schematic diagram of GMI four-point calibration.**

For cold load + noise diode measurement, the equation is:

$$T_{cn} = T_e + T_n = X_{cn} * T_h + (1-X_{cn}) * T_e - 4 * T_{nl} * X_{cn} * (1-X_{cn}) \quad (2.17)$$

where:  $T_n$ : noise diode excess temperature.

$$X_{cn} = (C_{cn} - C_c) / (C_h - C_c)$$

$C_{cn}$  : Cold Load + Noise Diode Count

The equation is similar for hot load + noise diode measurement:

$$T_{hn} = T_h + T_n = X_{hn} * T_h + (1 - X_{hn}) * T_c - 4 * T_{nl} * X_{hn} * (1 - X_{hn}) \quad (2.18)$$

where

$$X_{hn} = (C_{hn} - C_c) / (C_h - C_c)$$

$C_{hn}$  : Hot Load + Noise Diode Count

The nonlinearity can be derived from equation (2.17) and (2.18):

$$T_{nl} = (T_h - T_c) / 4 * (X_{hn} - X_{cn} - 1) / (X_{hn} (1 - X_{hn}) - X_{cn} (1 - X_{cn})) \quad (2.19)$$

And then the  $T_n$  can be determined by either (2.17) or (2.18).

### 2.1.8 Back-up Calibration and Blanking Algorithm

Using  $C_{cn}$  and trended  $T_{cn} = T_c + T_n$  we may derive a hot load back-up algorithm in case there is no hot load information for a section with more than 20 scans:

The trended  $T_n$  can be derived from the look-up table as a function of diode temperatures (data can be found in Appendix C).

$$T_a = X_b * T_{cn} + (1 - X_b) * T_c - 4 * T_{nl} * X_b * (1 - X_b) \quad (2.20)$$

$$\text{where: } X_b = (C - C_c) / (C_{cn} - C_c) \quad (2.21)$$

#### Blanking

If blanking is on, the following correction is made to derive a corrected Earth count  $C_{corr}$ :

$$C_{corr} = (C - 32500) \frac{t_{int}}{t_{int} - N_B t_B} + 32500 \quad (2.22)$$

where  $t_{int}$  is the nominal integration period of 0.00355 seconds,  $N_B$  is the effective number of blanking pulses during an integration period, and  $t_B$  is the blanking duration. The corrected Earth count  $C_{corr}$  is then used to compute  $T_a$ .

## 2.2 ANTENNA PATTERN CORRECTION

Corrections of the calibrated antenna temperatures are performed following the radiometric calibration in order to transform calibrated antenna temperature to brightness temperature. The antenna pattern correction involves first correcting for the antenna spillover.

For vertical polarized channels

$$T_a^{v1} = T_a / \eta_v - T_c (1 - \eta_v) / \eta_v \quad (2.23)$$

For horizontal polarized channels

$$T_a^{h1} = T_a / \eta_h - T_c (1 - \eta_h) / \eta_h \quad (2.24)$$

where  $\mathbf{T}_a$  is the measured antenna temperature,  $\eta_v$  and  $\eta_h$  are the spillover coefficients for V and H channels, and  $\mathbf{T}_c$  is the radiometric temperature of cold space, corrected for the approximation to the Rayleigh-Jeans law. Values of  $T_c$  for each channel are given in Table 2.5.  $\eta_v$  and  $\eta_h$  for all channels are given in Table 2.11.

**Table 2.11. Coefficients for computing APC.**

f [GHz]	10.65	18.7	23.8	36.64	89.0	166.0	183.31
$a_{vh}$	0.00363	0.00280	0.00211*	0.00094	0.00119	0.01339	0.01104*
$a_{hv}$	0.00366	0.00292	N/A	0.00094	0.00119	0.01339	N/A
$\eta_v$	0.94435	0.93968	0.96601*	0.99590	0.99810	1.00000	1.00000*
$\eta_h$	0.94369	0.94082	N/A	0.99590	0.99810	1.00000	N/A
$1-\eta_v$	0.05565	0.06032	0.03399*	0.00410	0.00190	0.00000	0.00000*
$1-\eta_h$	0.05631	0.05918	N/A	0.00410	0.00190	0.00000	N/A
$\lambda$	N/A	N/A	1.03386	N/A	N/A	N/A	1.00000
$\xi$	N/A	N/A	0.28259	N/A	N/A	N/A	0.00000
R	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

Secondly, the APC corrects for the emissivity of the reflector.

$$\mathbf{T}_a^v = \mathbf{T}_a^{v1}/R + \mathbf{T}_{refl}(1-R)/R \quad (2.25)$$

$$\mathbf{T}_a^h = \mathbf{T}_a^{h1}/R + \mathbf{T}_{refl}(1-R)/R \quad (2.26)$$

where  $\mathbf{R}$  is the RF reflectivity of the main reflector, and  $\mathbf{T}_{refl}$  is the measured temperature of the reflector. The values of R are given in Table 2.8. Since R=1:

$$\mathbf{T}_a^v = \mathbf{T}_a^{v1} \quad (2.27)$$

$$\mathbf{T}_a^h = \mathbf{T}_a^{h1} \quad (2.28)$$

Thirdly, the APC corrects for the cross polarization:

$$\mathbf{T}_b^v = ((1-a_{hv}) \mathbf{T}_a^v - a_{vh} \mathbf{T}_a^h) / (1 - a_{hv} - a_{vh}) \quad (2.29)$$

$$\mathbf{T}_b^h = ((1-a_{vh}) \mathbf{T}_a^h - a_{hv} \mathbf{T}_a^v) / (1 - a_{hv} - a_{vh}) \quad (2.30)$$

Values of  $a_{hv}$  and  $a_{vh}$  are given in Table 2.8.

Substitute equations (2.24) to (2.8) to equations (2.29) and (2.30), we can get:

$$\mathbf{T}_b^v = C_n^v \mathbf{T}_a^v - D_n^v \mathbf{T}_a^h - E_n^v \quad (2.31)$$

$$\mathbf{T}_b^h = C_n^h \mathbf{T}_a^h - D_n^h \mathbf{T}_a^v - E_n^h \quad (2.32)$$

where

$$C_n^v = (1-a_{hv}) / (\eta_v(1-a_{hv}-a_{vh}))$$

$$D_n^v = a_{vh} / (\eta_h(1-a_{hv}-a_{vh}))$$

$$E_n^v = T_c[(1 - \eta_v)(1 - a_{hv}) / (\eta_v - (1 - \eta_h)a_{vh}/\eta_h)] / (1 - a_{hv} - a_{vh})$$

$$C_n^h = (1 - a_{vh}) / (\eta_h(1 - a_{hv} - a_{vh}))$$

$$D_n^h = a_{hv} / (\eta_v(1 - a_{hv} - a_{vh}))$$

$$E_n^h = T_c[(1 - \eta_h)(1 - a_{vh}) / (\eta_h - (1 - \eta_v)a_{hv}/\eta_v)] / (1 - a_{hv} - a_{vh})$$

Equations (2.31) and (2.32) can be combined into equation (2.33):

$$T_b = C_n T_a - D_n T_a^* - E_n \quad (2.33)$$

$T_a^*$ : Antenna temperature of cross-polarized channel of the  $T_a$ .

For 23 GHz and 183 GHz channels, there are no cross-polarized channels; equation (2.33) is simplified to:

$$T_b = C_n T_a - E_n$$

The value of  $C_n$  and  $E_n$  for these channels are given in table 2.10:

$C_n = \lambda$ ,  $E_n = -\xi$ , for each corresponding channel.

**Table 2.12. Coefficients for computing APC  $C_n$ ,  $D_n$ , and  $E_n$ .**

Channel	$C_n$	$D_n$	$E_n$
1	1.062802	0.003875	0.161459
2	1.063577	0.003904	0.163503
3	1.067189	0.002993	0.176538
4	1.066024	0.003125	0.172972
5	1.033860	0.000000	-0.282590
6	1.005063	0.000946	0.011610
7	1.005063	0.000946	0.011610
8	1.003099	0.001195	0.006225
9	1.003099	0.001195	0.006225
10	1.013758	0.013758	0.000000
11	1.013758	0.013758	0.000000
12	1.000000	0.000000	0.000000
13	1.000000	0.000000	0.000000

In addition to the APC, the antenna effect on the earth view along-scan bias has been derived from data produced by Remote Sensing Systems together with data from the cold space maneuver and the correction is applied in the algorithm. The antenna effect is subdivided into two terms: an additive term and a multiplicative term. The additive portion most likely comes from the backlobes for the 10-23 GHz channels, while the multiplicative term comes from edge of scan effects such as the cold sky reflector MLI intruding into the sidelobes of the feeds. The correction is performed on the calibrated brightness temperatures (after the antenna pattern correction), and is represented as:

$$T_{b\text{-corr}} = T_b - \Delta T_{\text{const}} - (T_{\text{intru}} - T_b) \Delta t_{\text{multi}} \quad (2.34)$$

where

$T_b$  is the calibrated brightness temperature

$\Delta T_{\text{const}}$  is the constant along-scan bias term and can be found in Appendix D

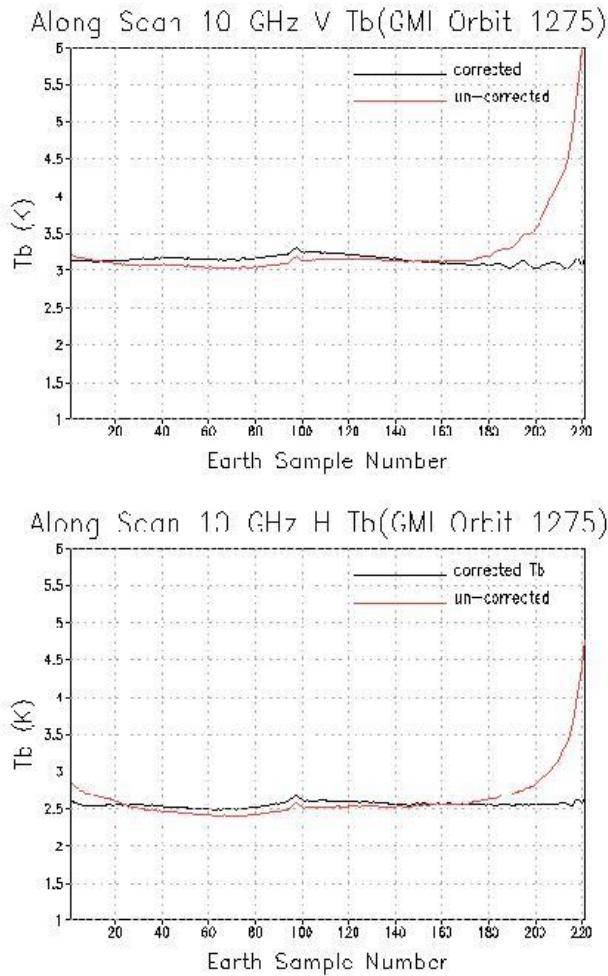
$T_{\text{intru}}$  is the temperature of the intrusion in Table 2.13

$\Delta t_{\text{multi}}$  is the multiplicative bias term (units of K/K) and can be found in Appendix E.

**Table 2.13. Values for  $T_{\text{intr}}$  for each GMI channel**

	10 V	10 H	18 V	18 H	23 V	36 V	36 H	89V	89H	166V	166H	183VA	183VB
$T_{\text{intru}}$	175	175	175	175	175	125	125	0	0	0	0	0	0

Figure 13 demonstrates the correction for 10 GHz V (upper panel) and 10 GHz H (lower panel) channels. Typically, the correction has large effects on samples near the edge of the scan. The correction is after the magnetism corrections described in Section 2.4 and therefore the both curves in the figures are already corrected for errors induced by magnetism.



**Figure 2.13. Along scan correction on Tb for 10 GHz channels. Red line: un-corrected, Black line: corrected.**

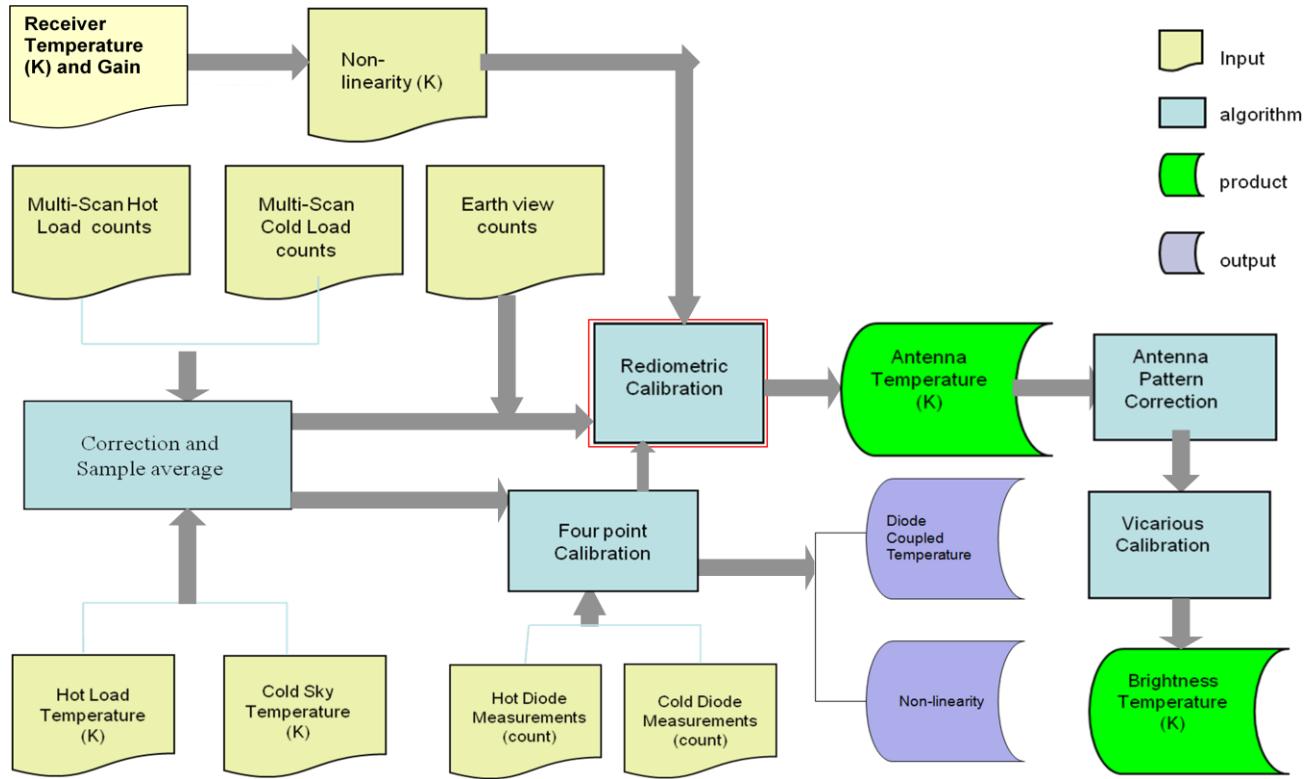
## 2.3 INPUT, OUTPUT, AND ALGORITHM FLOWCHART

The input files for calibration include three consecutive L1A files and external tuning files. The L1A includes already geolocated Earth counts, and SC and HK telemetry for the designed time period. There is one L1A file immediately before the processing orbit and one L1A file immediately after for the best multi-scan calibration. The tuning file will include all externally determined data such as APC coefficients and hot load PRT weights. Key input parameters are listed in Table 2.14 and the flow diagram of GMI calibration is displayed in Figure 2.14.

The key output parameters include geolocated and calibrated Ta and Tb, as well as parameters required by higher level algorithms such as incidence angle, Sun glint angle, etc. The details of output parameters are presented in separate documents: GMI Base File Specification, and GMI L1B File Specification.

**Table 2.14. Key input parameters.**

Parameter	Dimension	Unit	Description	Source
Noise Diode Indicator	$n_{scans}$		All Scans	SC Packets
Earth View Count	$n_{chan}, n_{scans}, n_{pixels}$	Counts	All Scans	SC Packets
Hot Load Count	$n_{chan}, n_{scans}, n_{hsample}$	Counts	Every Other Scan	SC Packets
Cold Load Count	$n_{chan}, n_{scans}, n_{csample}$	Counts	Every Other Scan	SC Packets
Hot Load + Noise Diode Count	$n_{chan}, n_{scans}, n_{hsample}$	Counts	Every Other Scan	SC Packets
Cold Load + Noise Diode Count	$n_{chan}, n_{scans}, n_{csample}$	Counts	Every Other Scan	SC Packets
Hot Load Temperature	$11, n_{scans}$	Kelvin	All Scans	SC Packets
Cold Sky Temperature	$n_{chan}, n_{scans}$	Kelvin	All Scans	Tuning Data
Hot Load Tray Temperature	$n_{scans}$		All Scans	SC Packets
APC Coefficients	$3, n_{chan}$		All Scans	Tuning Data
Nonlinearity	$3, n_{chan}$	Kelvin	All Scans	Tuning Data
Correction Tables	$n_{chan}, n_{pixels}$		All Scans	Tuning Data



**Figure 2.14. Flow chart of GMI L1B calibration process.**

The algorithm is written in C. The code design is demonstrated in Table 2.15.

**Table 2.15. L1B code design.**

main.c	Call getCommandLine.c to get input and output file information. Check all input files; if OK and not empty, call doScan.c. Close all files.
doScans.c	Call readTune.c, collectCalibrationData.c to collect calibration data. Start Loop to all scans: Call getScan.c to collect scan telemetry data. Call process.c to process the scan.
process.c	Call getSwath1.c and getSwath2.c to put geolocation data and L1A counts into the output data structure. Call missl1b.c to assign missing values for the rest of the output data structure. If the scan is not a missing scan: Call calscan.c to perform calibration and fill all output data structure. Call writescan.c to write out the output data into the output HDF file.
calscan.c	Perform radiometric calibration. If it is for GMIBASE, fill out all GMIBASE data structure. If it is for 1BGMI, call antencorr.c to perform antenna pattern correction and fill out all 1BGMI data structure.

## **2.4 DEEP SPACE MANEUVER AND CORRECTION ON ERROR INDUCED BY MAGNETIC FIELD**

During the deep space maneuver, it was found that the GMI receivers exhibit a small but detectable variation in output when exposed to a changing magnetic field. Each receiver exhibits the variation due to the earth magnetic field, observatory magnetic fields and instrument magnetic fields. The magnetometers on the spacecraft directly measure the magnetic field from the earth and spacecraft, which provides means for a correction of those terms. The combined earth and spacecraft magnetic field cause a one-cycle sinusoid across the full 360 degree scan. As for the instrument magnetic fields: two main sources of magnetic field have been identified: 1. spin mechanism, 2. feed switches on the launch restraints. The spin mechanism causes a small ripple in the counts at 96 cycles per revolution. The reed switches on the launch restraints cause blips in the scan as the receivers pass the launch restraints. The blips are most noticeable at the 10 GHz H-pol channel, the receiver closest to the IBS launch restraints, although they can also be seen in other channels. The change in receiver output due to instrument magnetic fields has now been shown to exist in GMI ground data and has been very stable from ground to on-orbit.

The magnetic correction is applied to the full-scan radiometer counts prior to calibration and has the following form:

$$C_{\text{corr}} = C - \mathbf{S} \cdot \mathbf{B} - \gamma \quad (2.35)$$

$C_{\text{corr}}$  represents the corrected counts from the receiver

$C$  represents the uncorrected counts from the receiver

The vector  $\mathbf{B}$  is the magnetic field vector. The vector  $\mathbf{S}$  is the susceptibility vector

And  $\gamma$  is a look-up table sample dependent bias that captures the variations due to the magnetics of the instrument and is given in Appendix F.

Or we can rewrite equation (2.35) as equation (2.36) by separating magnetic field  $\mathbf{v}_{\text{mag}}$  and scan angle  $\theta$ :

$$C_{\text{corr}} = C - \alpha(\mathbf{v}_{\text{mag}})\cos(\theta) - \beta(\mathbf{v}_{\text{mag}})\sin(\theta) - \delta(\mathbf{v}_{\text{mag}}) - \gamma \quad (2.36)$$

$\mathbf{v}_{\text{mag}}$  is the voltage output vector (x, y, z)

$\theta = 0.6912 * i$  is the scan angle of the sample,  $i$  is full-scan sample index starting at 1 and progressing to 500.

Dot coefficients  $\alpha(\mathbf{v}_{\text{mag}})$ ,  $\beta(\mathbf{v}_{\text{mag}})$ , and  $\delta(\mathbf{v}_{\text{mag}})$  are depend on whether magnetic fields derived from magnetometers on the spacecraft or derived from other source of earth magnetic field are used.

When using GPM TAM (Three Axis Magnetometer) reading from the spacecraft, the  $\mathbf{V}_{\text{mag}}$  (in volts) components are:

$$V_x = -15.0 + 0.007326 \times V_{\text{Counts}}(x)$$

$$V_y = -15.0 + 0.007326 \times V_{\text{Counts}}(y)$$

$$V_z = -15.0 + 0.007326 \times V_{\text{Counts}}(z)$$

and

$$\alpha(\mathbf{v}_{\text{mag}}) = \mathbf{V}_{\text{mag}} \cdot \mathbf{S}_a = V_x * S_a(x) + V_y * S_a(y)$$

$$\beta(\mathbf{v}_{\text{mag}}) = \mathbf{V}_{\text{mag}} \cdot \mathbf{S}_b = V_x * S_b(x) + V_y * S_b(y)$$

$$\delta(\mathbf{v}_{\text{mag}}) = 0.0$$

Magnetic susceptibility vector  $\mathbf{S}_a$  and  $\mathbf{S}_b$  are provided by BATC are shown in the following tables (Table 2.15 and Table 2.16):

**Table 16. BATC susceptibility vector  $\mathbf{S}_a$**

$\mathbf{S}_a$	Channels												
	10V	10H	18V	18H	23V	36V	36H	89V	89H	166V	166H	183±3	183±7
$S_a(x)$	2.4566	-4.6	0.9821	-1.782	2.3998	3.7706	1.6739	-0.2792	3.4051	-1.2956	-2.9619	-0.2307	-1.5386
$S_a(y)$	-2.9305	4.619	1.1131	-0.9076	1.1477	-5.8881	-2.2984	-0.2806	-0.4871	1.2812	4.2001	-1.1519	-3.9776
$S_a(z)$	0	0	0	0	0	0	0	0	0	0	0	0	0

**Table 17. BATC susceptibility vector  $\mathbf{S}_b$**

$\mathbf{S}_b$	Channels												
	10V	10H	18V	18H	23V	36V	36H	89V	89H	166V	166H	183±3	183±7
$S_b(x)$	2.6051	-2.4256	-0.3482	2.2221	-1.3746	4.8544	1.7936	0.5234	-0.5368	0.3828	-2.1692	1.7842	5.1143
$S_b(y)$	1.73	-2.7362	2.2958	-1.2728	3.4557	2.828	1.432	0.0853	3.9825	-0.9051	-1.5563	-0.0135	-2.0837
$S_b(z)$	0	0	0	0	0	0	0	0	0	0	0	0	0

The final implementation uses the earth magnetic fields based on International Geomagnetic Reference Field (IGRF) 2011 software and data. The major reason for this decision is that the GPM real time system doesn't have the input of magnetometer readings at the processing time and that the correction using IGRF 2011 is slightly better. The susceptibility vector  $\mathbf{S}$  in Table 2.15 is derived based on IGRF 2011 magnetic field. However, the correction using TAM data are tested and results are also evaluated.

When using the earth magnetic field based on IGRF 2011:

First we compute the volts from the earth magnetic filed by  $V_{volts} = 0.0001 * V_{earthmag}$

We rotate the  $V_{volts}$  two times to transform the  $V_{volts}$  from ECEF coordinate system into the GPM Flight axes  $\mathbf{Bs}$ (GeoTK ATBD).

The susceptibility vectors  $\mathbf{S}$  are provided by RSS and are shown in Table 2-18

$\mathbf{B} = \mathbf{R} \cdot \mathbf{Bs}$  where:

$$\mathbf{R} = \begin{matrix} \cos(\theta) & \sin(\theta) & 0 \\ -\sin(\theta) & \cos(\theta) & 0 \\ 0 & 0 & 1 \end{matrix} \quad \text{and } \mathbf{Bs} = \begin{matrix} Vx \\ Vy \\ Vz \end{matrix}$$

Using equation (2-35), we get:

$$C_{corr} = C - (S_x(V_x \cos(\theta) + V_y \sin(\theta)) + S_y(-V_x \sin(\theta) + V_y \cos(\theta)) + S_z V_z) - \gamma$$

Or:

$$\alpha(\mathbf{v}_{mag}) = S_x V_x + S_y V_y$$

$$\beta(\mathbf{v}_{mag}) = S_x V_y - S_y V_x$$

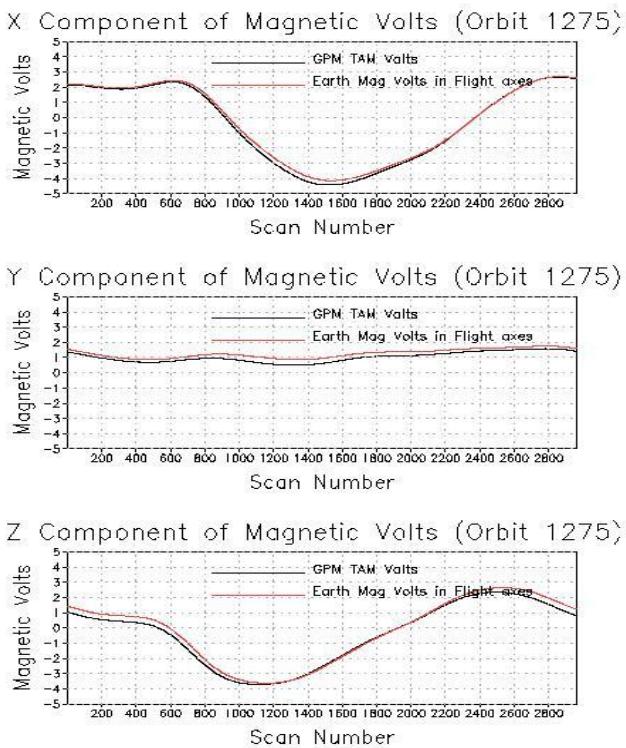
$$\delta(\mathbf{v}_{mag}) = S_z S_z$$

for equation (2.36)

**Table 18. RSS susceptibility vector S**

Channel	Sx	Sy	Sz
1	3.141988e+00	-2.254825e+00	1.540760e-01
2	-3.923139e+00	3.039834e+00	-5.977978e-02
3	1.399973e+00	5.585967e-01	-1.823223e-01
4	-1.296778e+00	-1.992376e+00	-1.155604e-01
5	2.645295e+00	1.484631e+00	-1.082659e-01
6	3.750354e+00	-4.926692e+00	-5.915702e-02
7	1.714678e+00	-1.818046e+00	-2.868201e-02
8	-1.222582e-01	-4.776692e-01	-5.772674e-02
9	3.602760e+00	5.355085e-01	-4.077761e-02
10	-1.246589e+00	-3.012716e-01	-8.712511e-02
11	-2.720068e+00	2.335972e+00	-9.152361e-02
12	-1.527656e-01	-1.759787e+00	-1.063396e-01
13	-1.274096e+00	-5.077661e+00	-8.178916e-02

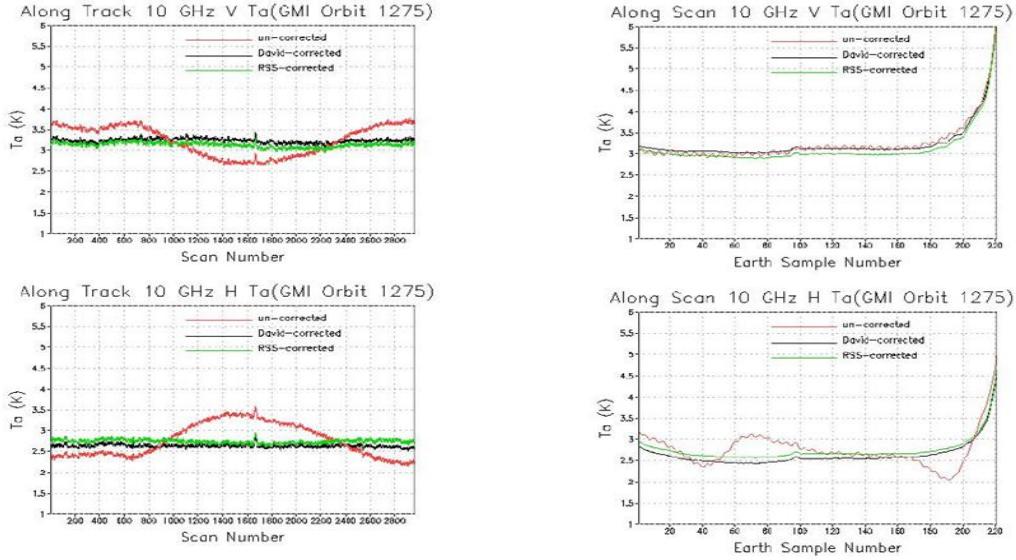
Following figures show the corrections on errors induced by magnetic (MAG) field for a DSC orbit. Figure 2.15 compares the magnetic fields from GPM housekeeping data (TAM reading) and from IGRF 2011. The results are consistent in the coordinate system. The contribution of space craft to the total magnetic field is small.



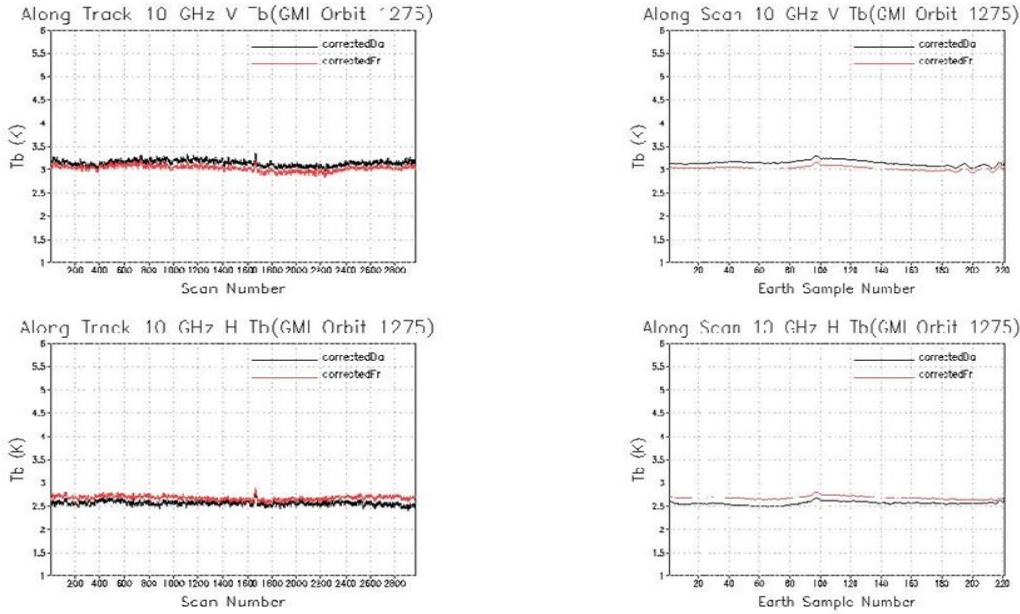
**Figure 2.15. Magnet volts from earth magnetic fields and GPM TAM**

Figure 2.16 are along track and along scan variations before and after magnetism corrections. The along track anomalies of 10 GHz V are resemble to the X-components of magnetic field before correction. The along track anomalies of 10 GHz H channel are out of phase with the X-components of magnetic field before correction. These variations are gone after magnetism

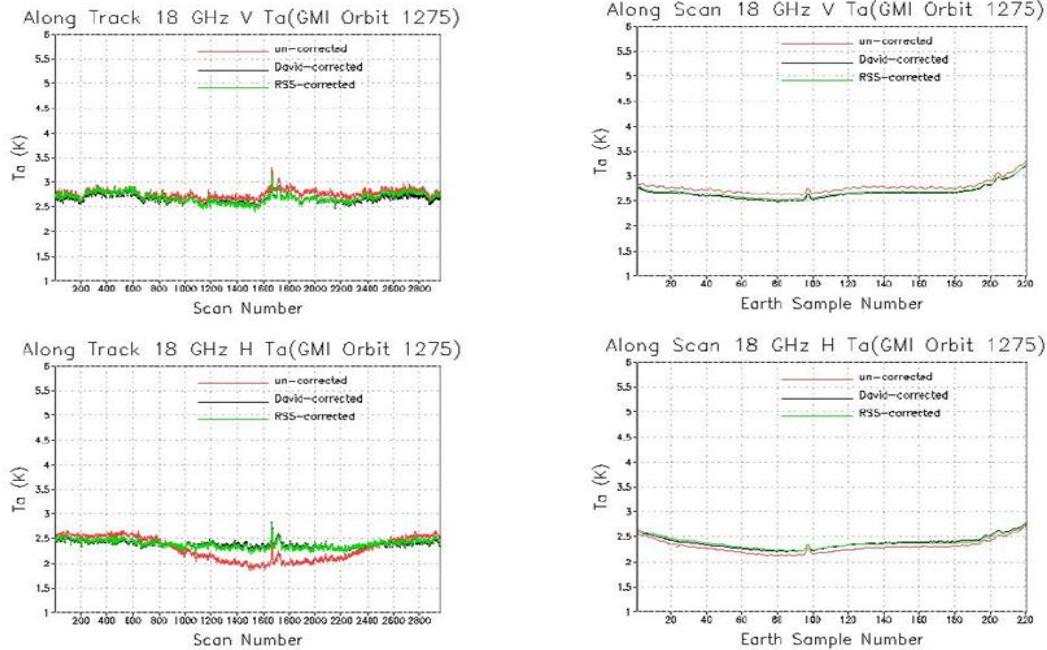
corrections. The along scan biases induced by magnetic field are corrected for Ta. However, the along scan biases due to antenna patterns are not corrected for Ta. These biases are large near the edge of scans. These are corrected in Tb (Figure 2.17). Figure 18 to Figure 29 demonstrate the magnetism and along scan corrections for all other channels.



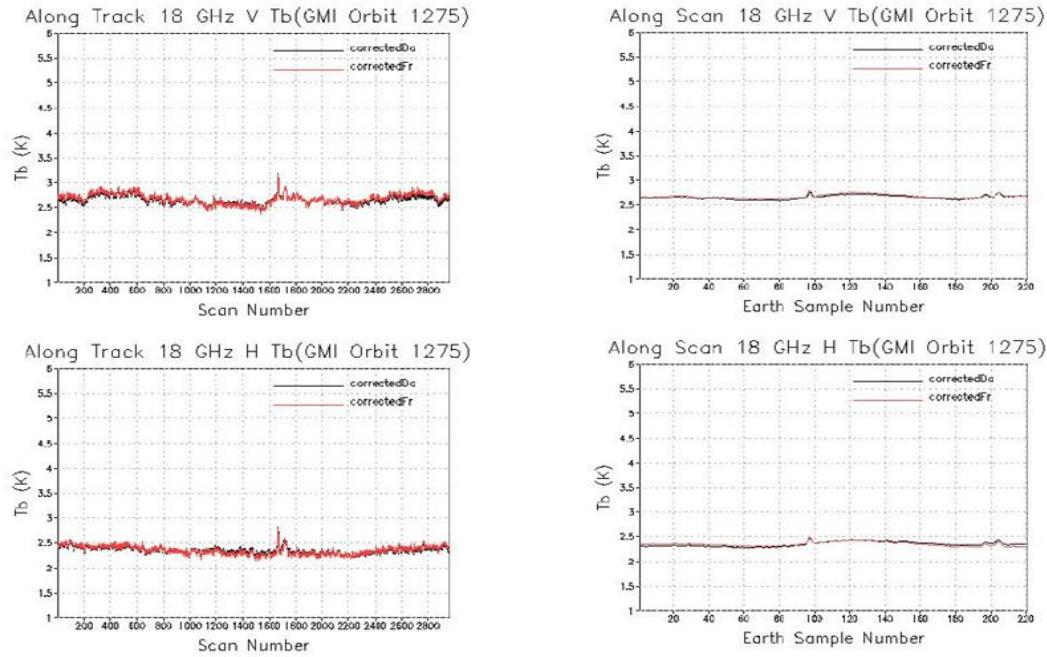
**Figure 2.16. MAG corrections for Ta of 10 GHz V and H channels. Left: along track. Right: along scan. The green line is the results implemented for both GMI production and NRT.**



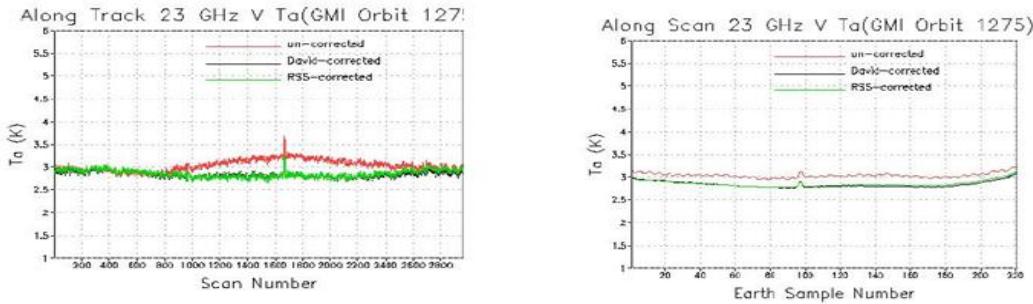
**Figure 2.17. MAG + APC corrections for Tb of 10 GHz V and H channels. Left: along track. Right: along scan. The red line is the results implemented for both GMI production and NRT.**



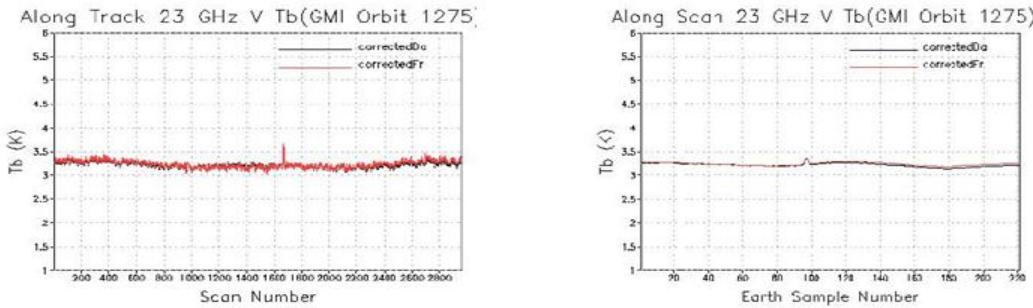
**Figure 2.18. MAG corrections for Ta of 18 GHz V and H channels. Left: along track. Right: along scan. The green line is the results implemented for both GMI production and NRT.**



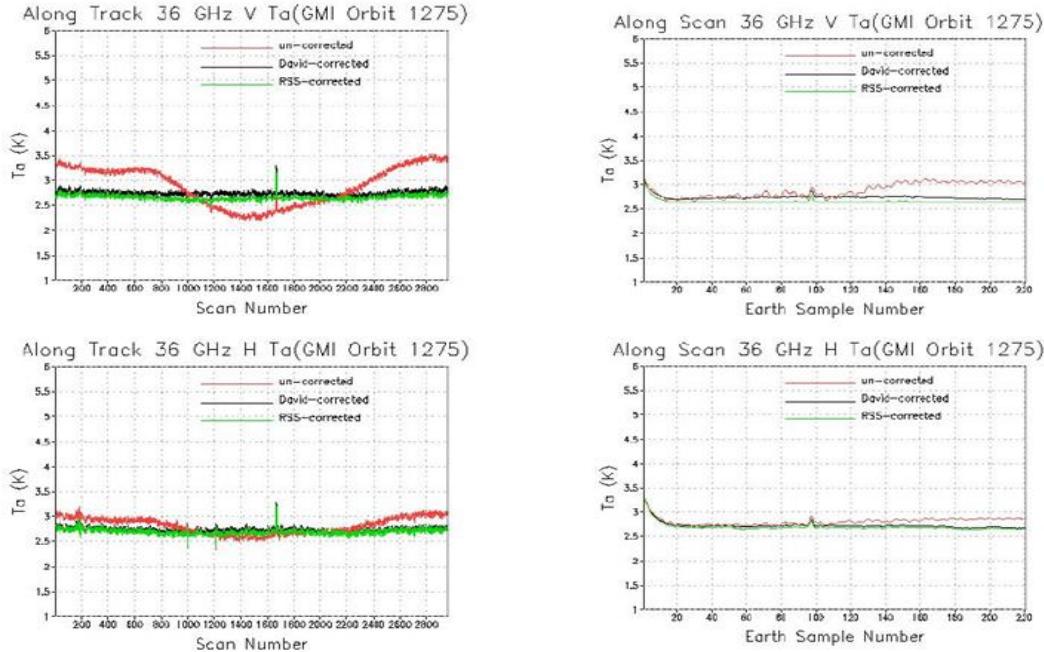
**Figure 2.19. MAG + APC corrections for Tb of 18 GHz V and H channels. Left: along track. Right: along scan. The red line is the results implemented for both GMI production and NRT.**



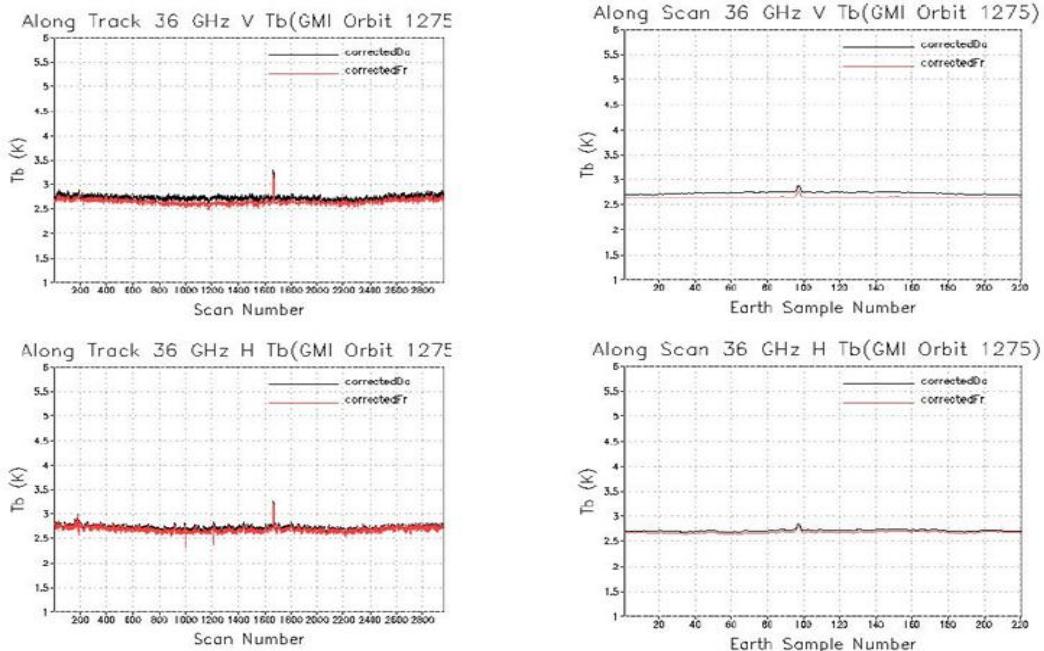
**Figure 2.20. MAG corrections for Ta of 23 GHz V and H channels. Left: along track. Right: along scan. The green line is the results implemented for both GMI production and NRT.**



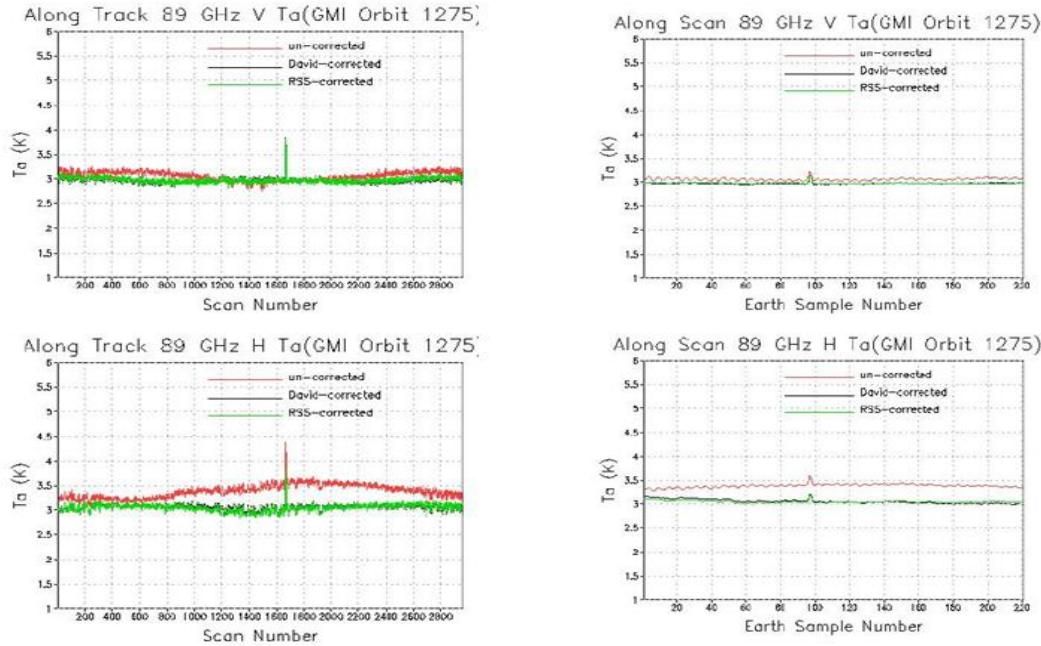
**Figure 2.21. MAG + APC corrections for Tb of 23 GHz V and H channels. Left: along track. Right: along scan. The red line is the results implemented for both GMI production and NRT.**



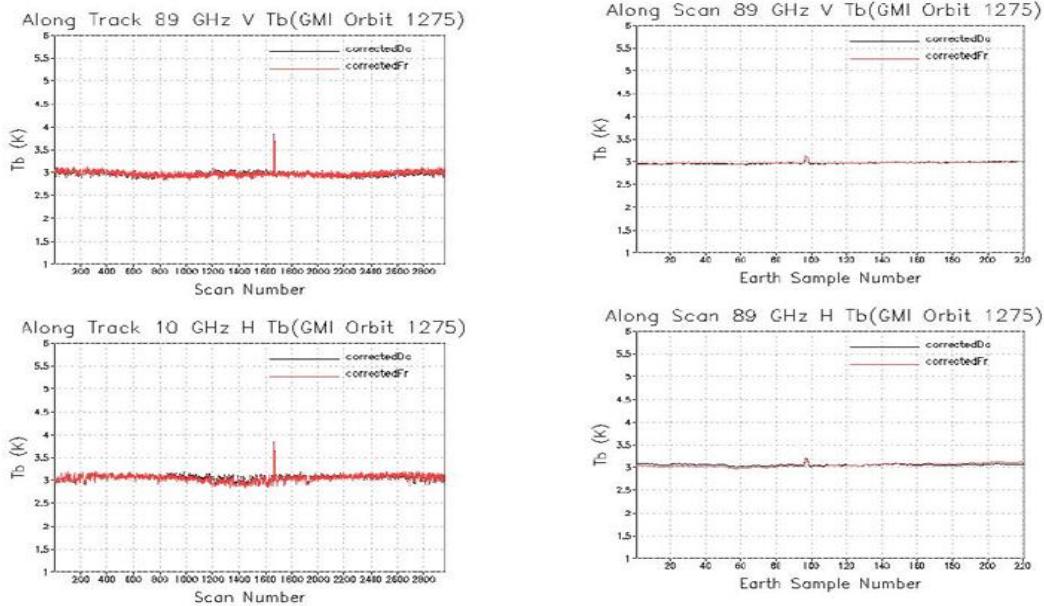
**Figure 2.22. MAG corrections for Ta of 36 GHz V and H channels. Left: along track. Right: along scan. The green line is the results implemented for both GMI production and NRT.**



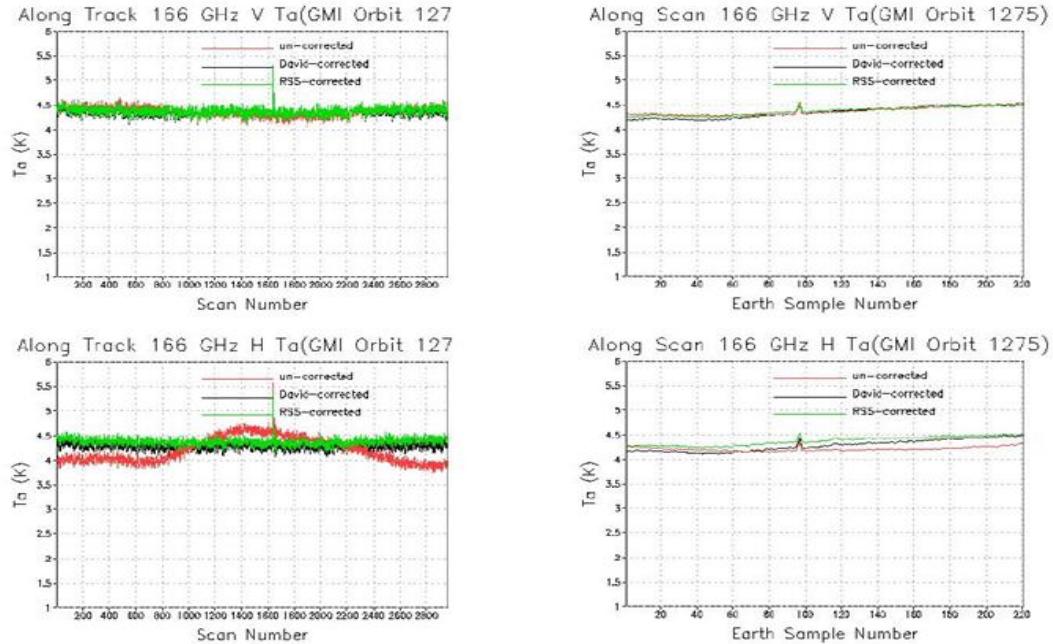
**Figure 2.23. MAG + APC corrections for Tb of 36 GHz V and H channels. Left: along track. Right: along scan. The red line is the results implemented for both GMI production and NRT.**



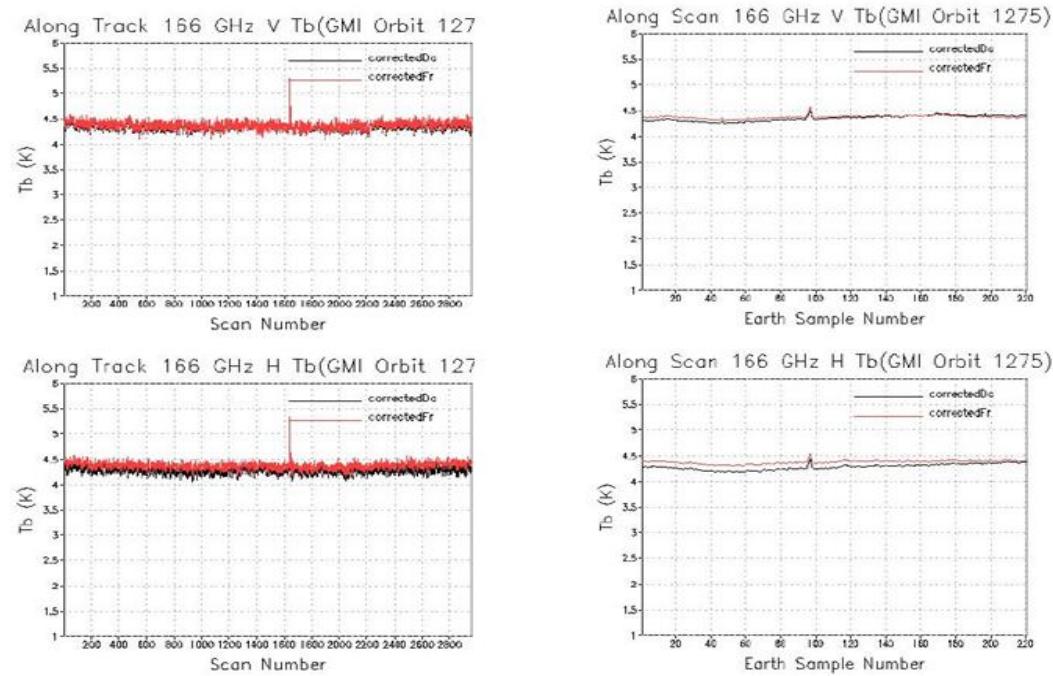
**Figure 2.24.** MAG corrections for Ta of 89 GHz V and H channels. Left: along track. Right: along scan. The green line is the results implemented for both GMI production and NRT.



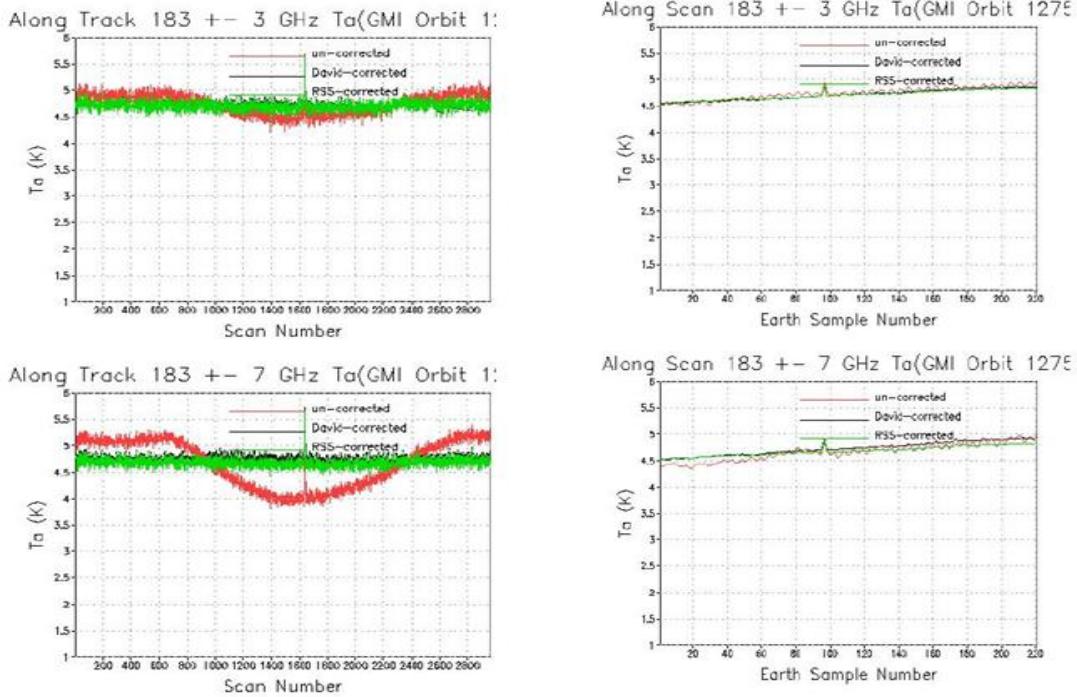
**Figure 2.25.** MAG + APC corrections for Tb of 89 GHz V and H channels. Left: along track. Right: along scan. The red line is the results implemented for both GMI production and NRT.



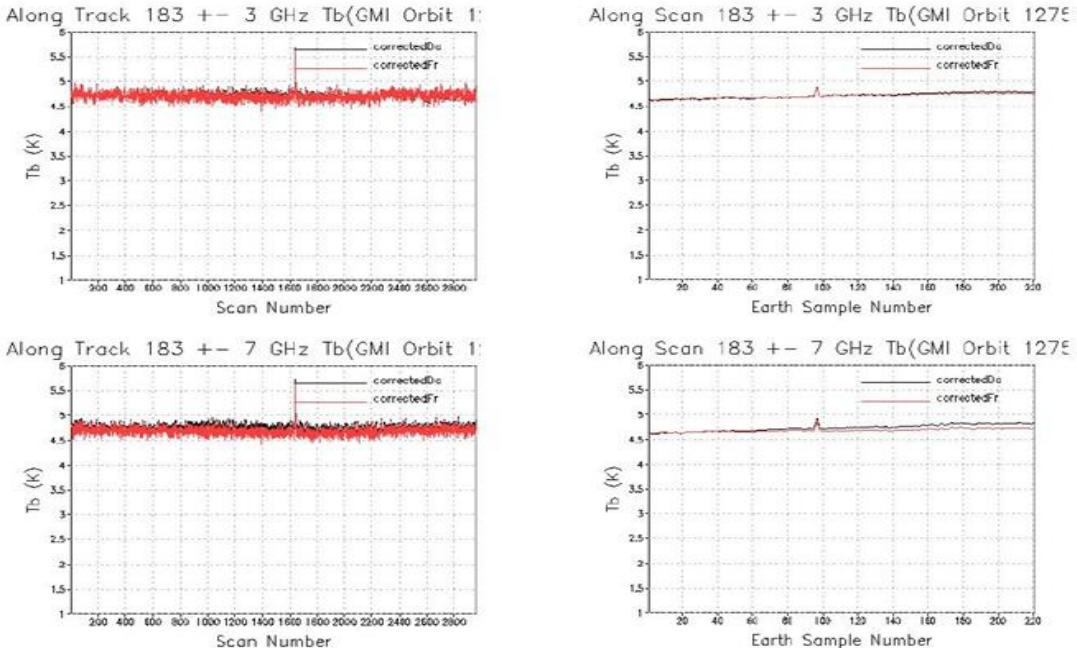
**Figure 2.26.** MAG corrections for Ta of 166 GHz V and H channels. Left: along track. Right: along scan. The green line is the results implemented for both GMI production and NRT.



**Figure 2.27.** MAG + APC corrections for Tb of 166 GHz V and H channels. Left: along track. Right: along scan. The red line is the results implemented for both GMI production and NRT.



**Figure 2.28. MAG corrections for Ta of  $183 \pm 3$  GHz and  $183 \pm 7$  GHz channels. Left: along track. Right: along scan. The green line is the results implemented for both GMI production and NRT.**

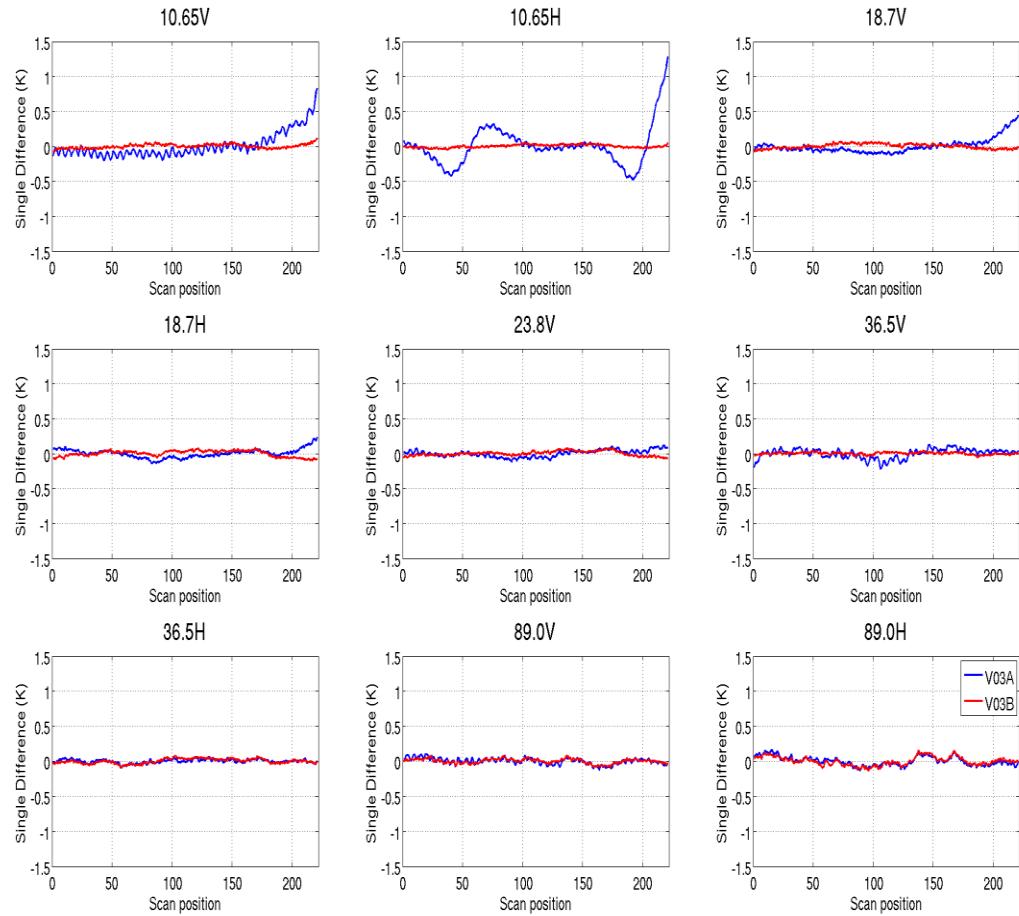


**Figure 2.29. MAG + APC corrections for Tb of of  $183 \pm 3$  GHz and  $183 \pm 7$  GHz channels. Left: along track. Right: along scan. The red line is the results implemented for both GMI production and NRT.**

## 2.5 POST-LAUNCH VALIDATION

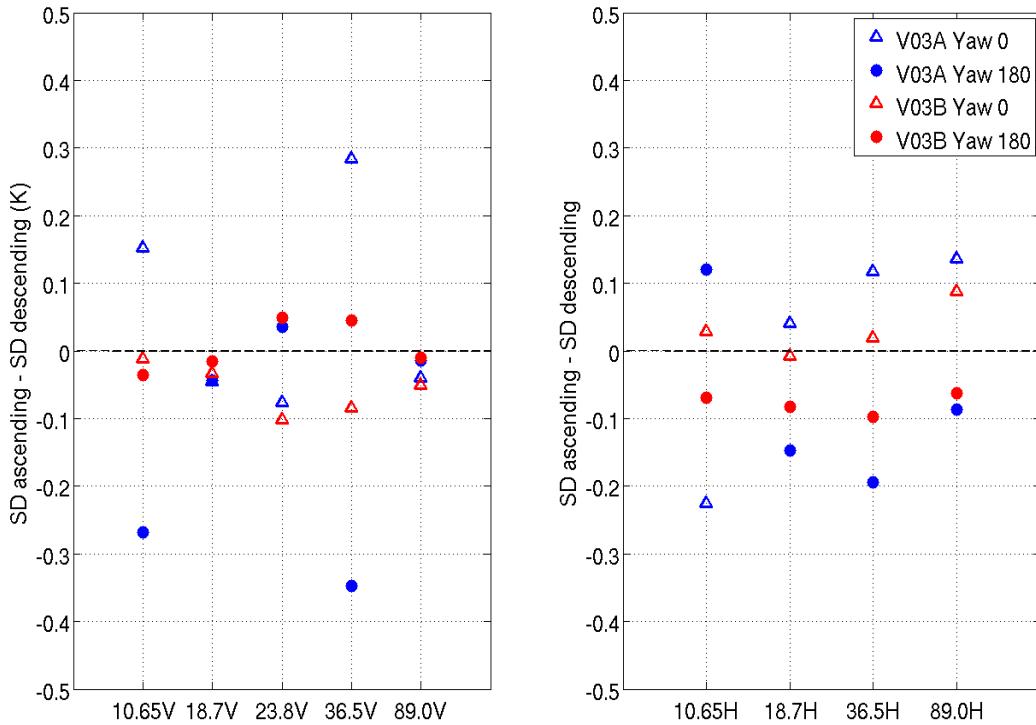
In addition to the validation described in Section 2.2 and Section 2.4, analyses are performed to compare biases between current production (V03B) and an earlier version (V03A) of production for the period when data are available.

V03B corrects the scan biases seen in many of the channels, most notably in 10.65H. The corrections added to V03B are combinations of magnetism correction described in Section 2.4 and along scan antenna pattern correction described in Section 2.2. Figure 2.30 shows the scan biases for the nine low frequency channels. The scan biases are shown as single differences (SD) using the vicarious cold calibration method. Single differences calculated using GMI 1C V03A are shown in blue and V03B are shown in red.



**Figure 2.30: Vicarious cold calibration single differences by scan position for V03A (blue) and V03B (red). V03B scan biases show less variation across the scan than V03A, most notably for 10.65H.**

V03B also corrects for the magnetic anomaly in the data that appears when splitting the data by yaw orientation and ascending/descending orbits. Figure 2.31 shows the vicarious cold calibration single differences, shown as the ascending SD minus the descending SD at each yaw orientation. This value should ideally be zero, however, some channels show a discrepancy using the V03A data. This is most obvious at 36.5V. V03B corrects for this discrepancy, reducing it to <0.1 K.



**Figure 2.31: Ascending – descending SDs by yaw orientation for V03A (blue) and V03B (red). V03B reduces the discrepancy between the ascending and descending SDs, most notably at 36.5V.**

The NEDT for cold load counts for 13 GMI channels are shown in Figure 2.32. Values before orbit number 720 are those derived from the at-launch version of products and values thereafter are those derived from the after-launch adjustments. For cold counts, the adjustment reduced NEDT significantly for Channels 3-9. The adjustment doesn't affect the hot load NEDT significantly (Figure 2.33).

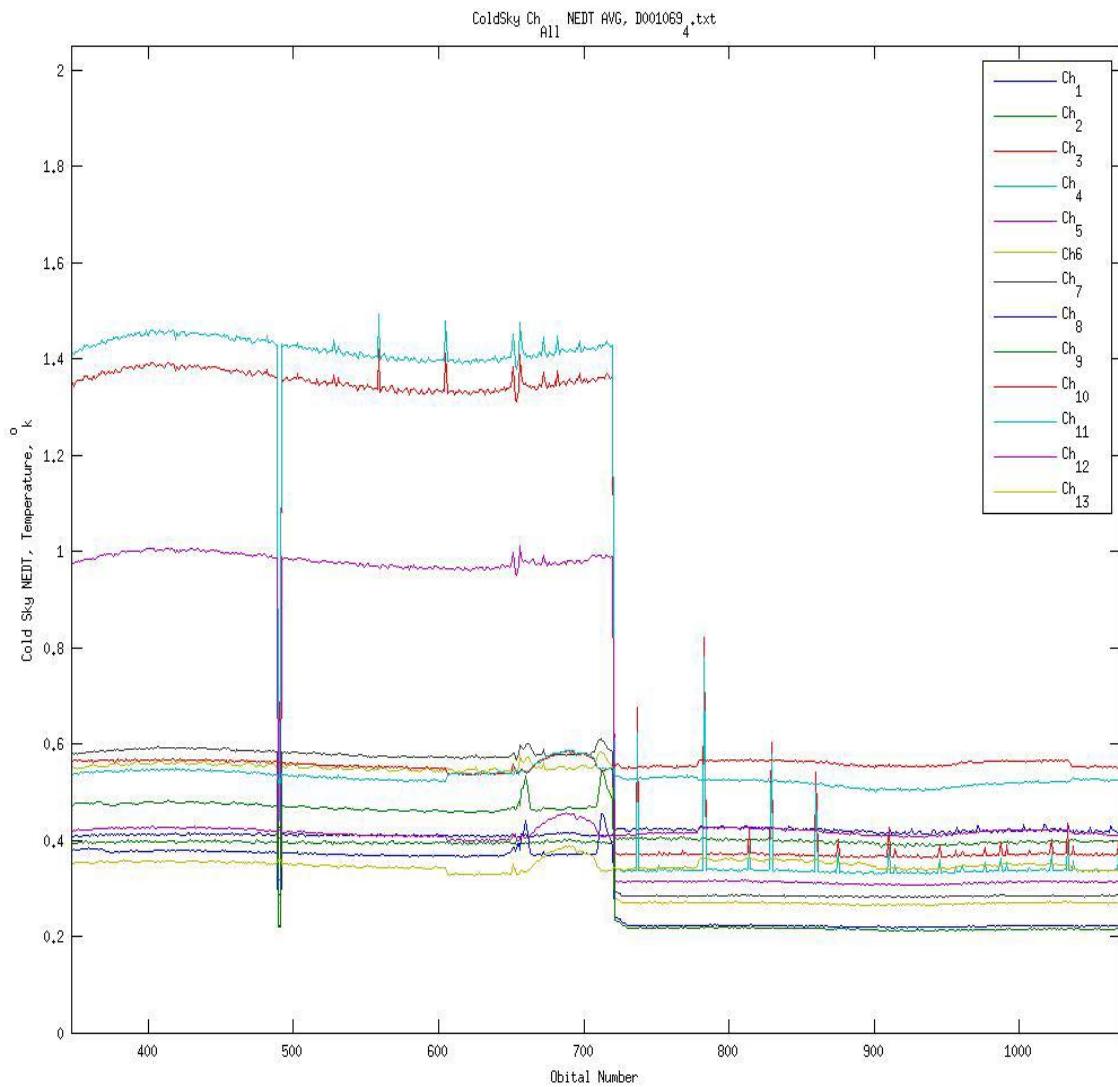


Figure 2.32: Cold Load NEDT for 13 GMI channels.

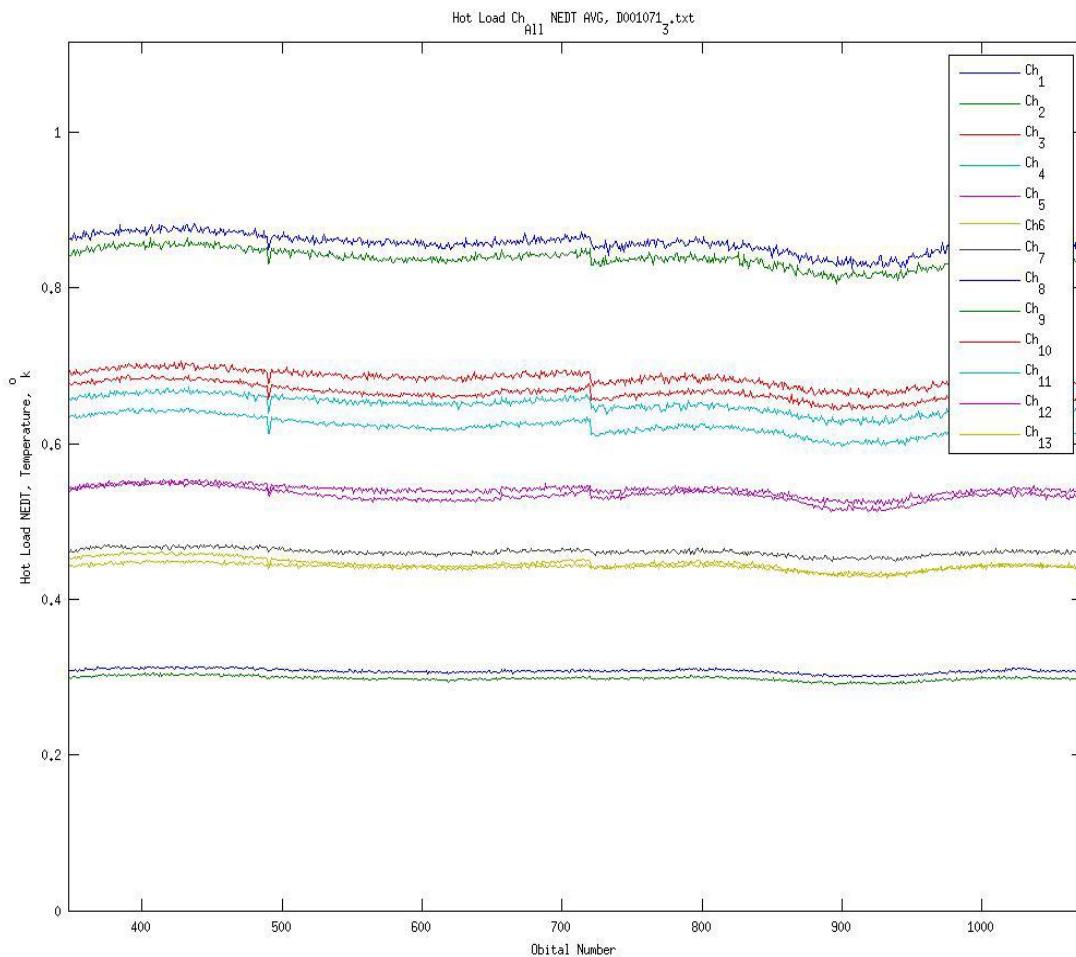


Figure 2.33: Hot Load NEDT for 13 GMI channels.

### 3. REFERENCES

1. Bilanow, S., 2010: PPS Geolocation Toolkit ATBD.
2. Bilanow, S., 2010: PPS Geolocation Toolkit Architecture and Design Specification.
3. Stout, J. M., 2010: PPS File Specification.
4. Wentz, F. J., and M. Thomas, 2008: GMI Calibration ATBD.
5. BATC, 2014: GMI Calibration Data Book.

#### **4. ACRONYMS**

ACS	Attitude Control System
AMSR	Advanced Microwave Scanning Radiometer
AMSU	Advanced Microwave Sounding Unit
APC	Antenna Pattern Correction
ATBD	Algorithm Theoretical Basis Document
BATC	Ball Aerospace & Technologies Corp.
CSR	Cold Sky Reflector
DPR	Dual-Frequency Precipitation Radar
ECS	EOSDIS Core System
EOS	Earth Observing System
EOSDIS	Earth Observing System Data and Information System
ETE	End-to-End Test
GCI	Geocentric Coordinates Inertial
GHA	Greenwich Hour Angle
GHz	Gigahertz
GICS	GMI Coordinate System
GMI	GPM Microwave Imager
GPM	Global Precipitation Measurement
GSFC	Goddard Space Flight Center (Greenbelt, MD)
HDF	Hierarchical Data Format
HK	Housekeeping
IFOV	Instantaneous Field of View
L1A	Level 1A
L1B	Level 1B
MOC	Mission Operations Center
NASA	National Aeronautics and Space Administration
NOAA	National Oceanic and Atmospheric Administration
PDL	Program Design Language
PPS	Precipitation Processing System
PRT	Platinum Resistance Thermometer
RF	Radio Frequency
RSS	Remote Sensing Systems
SC	Spacecraft
SSMI	Special Sensor for Microwave Imager
SSMI/S	Special Sensor for Microwave Imager/Sounder
Ta	Antenna Temperature
Tb	Brightness Temperature
TMI	TRMM Microwave Imager
TRMM	Tropical Rainfall Measuring Mission
UTC	Universal Time Coordinates
X-Cal	Intercalibration Working Group (GPM)

## **5. APPENDIX A. NONLINEARITY PARAMETER "U"**

Nonlinearity parameter "u"

Temp (°C)	10 GHz V			10 GHz H		
	Low Gain	Nom Gain	High Gain	Low Gain	Nom Gain	High Gain
-10.0	-6.646000e-06	-8.455000e-06	-8.489000e-06	-7.507000e-06	-8.864000e-06	-1.130150e-05
-9.0	-6.606000e-06	-8.358000e-06	-8.367000e-06	-7.354000e-06	-8.741000e-06	-1.107250e-05
-8.0	-6.564000e-06	-8.262000e-06	-8.246000e-06	-7.205000e-06	-8.619000e-06	-1.084750e-05
-7.0	-6.520000e-06	-8.166000e-06	-8.125000e-06	-7.058000e-06	-8.498000e-06	-1.062640e-05
-6.0	-6.476000e-06	-8.070000e-06	-8.006000e-06	-6.913000e-06	-8.377000e-06	-1.040920e-05
-5.0	-6.430000e-06	-7.975000e-06	-7.888000e-06	-6.772000e-06	-8.257000e-06	-1.019590e-05
-4.0	-6.382000e-06	-7.880000e-06	-7.771000e-06	-6.632000e-06	-8.138000e-06	-9.986590e-06
-3.0	-6.334000e-06	-7.786000e-06	-7.654000e-06	-6.496000e-06	-8.020000e-06	-9.781200e-06
-2.0	-6.284000e-06	-7.692000e-06	-7.539000e-06	-6.362000e-06	-7.902000e-06	-9.579740e-06
-1.0	-6.233000e-06	-7.598000e-06	-7.425000e-06	-6.230000e-06	-7.786000e-06	-9.382210e-06
0.0	-6.180000e-06	-7.504000e-06	-7.312000e-06	-6.101000e-06	-7.670000e-06	-9.188610e-06
1.0	-6.126000e-06	-7.411000e-06	-7.200000e-06	-5.975000e-06	-7.554000e-06	-8.998940e-06
2.0	-6.071000e-06	-7.319000e-06	-7.088000e-06	-5.852000e-06	-7.440000e-06	-8.813210e-06
3.0	-6.014000e-06	-7.226000e-06	-6.978000e-06	-5.730000e-06	-7.326000e-06	-8.631400e-06
4.0	-5.956000e-06	-7.134000e-06	-6.869000e-06	-5.612000e-06	-7.213000e-06	-8.453530e-06
5.0	-5.897000e-06	-7.043000e-06	-6.761000e-06	-5.496000e-06	-7.100000e-06	-8.279590e-06
6.0	-5.836000e-06	-6.952000e-06	-6.653000e-06	-5.383000e-06	-6.989000e-06	-8.109590e-06
7.0	-5.774000e-06	-6.861000e-06	-6.547000e-06	-5.272000e-06	-6.878000e-06	-7.943510e-06
8.0	-5.711000e-06	-6.770000e-06	-6.442000e-06	-5.164000e-06	-6.768000e-06	-7.781360e-06
9.0	-5.646000e-06	-6.680000e-06	-6.337000e-06	-5.059000e-06	-6.658000e-06	-7.623150e-06
10.0	-5.580000e-06	-6.591000e-06	-6.234000e-06	-4.956000e-06	-6.550000e-06	-7.468870e-06
11.0	-5.513000e-06	-6.501000e-06	-6.132000e-06	-4.855000e-06	-6.442000e-06	-7.318520e-06
12.0	-5.444000e-06	-6.412000e-06	-6.031000e-06	-4.758000e-06	-6.335000e-06	-7.172100e-06
13.0	-5.374000e-06	-6.324000e-06	-5.930000e-06	-4.663000e-06	-6.228000e-06	-7.029620e-06
14.0	-5.303000e-06	-6.235000e-06	-5.831000e-06	-4.570000e-06	-6.123000e-06	-6.891060e-06
15.0	-5.231000e-06	-6.148000e-06	-5.733000e-06	-4.480000e-06	-6.018000e-06	-6.756440e-06
16.0	-5.157000e-06	-6.060000e-06	-5.635000e-06	-4.393000e-06	-5.913000e-06	-6.625750e-06
17.0	-5.081000e-06	-5.973000e-06	-5.539000e-06	-4.308000e-06	-5.810000e-06	-6.498990e-06
18.0	-5.005000e-06	-5.886000e-06	-5.444000e-06	-4.226000e-06	-5.707000e-06	-6.376160e-06
19.0	-4.927000e-06	-5.800000e-06	-5.349000e-06	-4.146000e-06	-5.605000e-06	-6.257270e-06
20.0	-4.847000e-06	-5.714000e-06	-5.256000e-06	-4.070000e-06	-5.504000e-06	-6.142300e-06
21.0	-4.767000e-06	-5.628000e-06	-5.164000e-06	-3.995000e-06	-5.404000e-06	-6.031270e-06
22.0	-4.685000e-06	-5.543000e-06	-5.072000e-06	-3.923000e-06	-5.304000e-06	-5.924170e-06
23.0	-4.602000e-06	-5.458000e-06	-4.982000e-06	-3.854000e-06	-5.205000e-06	-5.821000e-06
24.0	-4.517000e-06	-5.373000e-06	-4.893000e-06	-3.788000e-06	-5.107000e-06	-5.721760e-06
25.0	-4.431000e-06	-5.289000e-06	-4.804000e-06	-3.724000e-06	-5.009000e-06	-5.626460e-06
26.0	-4.344000e-06	-5.205000e-06	-4.717000e-06	-3.662000e-06	-4.912000e-06	-5.535080e-06
27.0	-4.255000e-06	-5.122000e-06	-4.631000e-06	-3.604000e-06	-4.816000e-06	-5.447640e-06
28.0	-4.165000e-06	-5.039000e-06	-4.545000e-06	-3.547000e-06	-4.721000e-06	-5.364130e-06
29.0	-4.074000e-06	-4.956000e-06	-4.461000e-06	-3.494000e-06	-4.627000e-06	-5.284550e-06
30.0	-3.981000e-06	-4.874000e-06	-4.377000e-06	-3.443000e-06	-4.533000e-06	-5.208900e-06
31.0	-3.887000e-06	-4.792000e-06	-4.295000e-06	-3.394000e-06	-4.440000e-06	-5.137190e-06
32.0	-3.792000e-06	-4.710000e-06	-4.214000e-06	-3.349000e-06	-4.347000e-06	-5.069400e-06

33.0 -3.696000e-06 -4.629000e-06 -4.133000e-06 -3.305000e-06 -4.256000e-06 -5.005550e-06  
 34.0 -3.598000e-06 -4.548000e-06 -4.054000e-06 -3.265000e-06 -4.165000e-06 -4.945630e-06  
 35.0 -3.498000e-06 -4.468000e-06 -3.975000e-06 -3.227000e-06 -4.075000e-06 -4.889640e-06  
 36.0 -3.398000e-06 -4.387000e-06 -3.898000e-06 -3.191000e-06 -3.986000e-06 -4.837580e-06  
 37.0 -3.296000e-06 -4.308000e-06 -3.822000e-06 -3.159000e-06 -3.897000e-06 -4.789460e-06  
 38.0 -3.193000e-06 -4.228000e-06 -3.746000e-06 -3.128000e-06 -3.809000e-06 -4.745260e-06  
 39.0 -3.088000e-06 -4.149000e-06 -3.672000e-06 -3.101000e-06 -3.722000e-06 -4.705000e-06  
 40.0 -2.982000e-06 -4.071000e-06 -3.598000e-06 -3.076000e-06 -3.636000e-06 -4.668670e-06  
 41.0 -2.875000e-06 -3.992000e-06 -3.526000e-06 -3.053000e-06 -3.550000e-06 -4.636270e-06  
 42.0 -2.766000e-06 -3.914000e-06 -3.454000e-06 -3.033000e-06 -3.465000e-06 -4.607800e-06  
 43.0 -2.656000e-06 -3.837000e-06 -3.384000e-06 -3.016000e-06 -3.381000e-06 -4.583270e-06  
 44.0 -2.545000e-06 -3.760000e-06 -3.315000e-06 -3.001000e-06 -3.298000e-06 -4.562670e-06  
 45.0 -2.432000e-06 -3.683000e-06 -3.246000e-06 -2.989000e-06 -3.215000e-06 -4.545990e-06

Temp (°C)	18 GHz V			18 GHz H		
	Low Gain	Nom Gain	High Gain	Low Gain	Nom Gain	High Gain
-10.0	-1.607120e-06	-2.020000e-06	-1.292400e-06	4.404120e-07	9.944000e-07	2.942460e-06
-9.0	-1.583660e-06	-1.960000e-06	-1.278210e-06	4.594960e-07	1.070000e-06	2.985510e-06
-8.0	-1.560160e-06	-1.890000e-06	-1.263370e-06	4.786690e-07	1.145000e-06	3.028340e-06
-7.0	-1.536630e-06	-1.830000e-06	-1.247900e-06	4.979310e-07	1.218000e-06	3.070950e-06
-6.0	-1.513070e-06	-1.770000e-06	-1.231790e-06	5.172830e-07	1.290000e-06	3.113330e-06
-5.0	-1.489480e-06	-1.710000e-06	-1.215040e-06	5.367250e-07	1.361000e-06	3.155500e-06
-4.0	-1.465860e-06	-1.650000e-06	-1.197650e-06	5.562560e-07	1.430000e-06	3.197440e-06
-3.0	-1.442210e-06	-1.590000e-06	-1.179620e-06	5.758770e-07	1.498000e-06	3.239150e-06
-2.0	-1.418530e-06	-1.540000e-06	-1.160950e-06	5.955880e-07	1.565000e-06	3.280650e-06
-1.0	-1.394830e-06	-1.480000e-06	-1.141640e-06	6.153880e-07	1.631000e-06	3.321920e-06
0.0	-1.371090e-06	-1.430000e-06	-1.121700e-06	6.352770e-07	1.695000e-06	3.362970e-06
1.0	-1.347320e-06	-1.370000e-06	-1.101110e-06	6.552570e-07	1.758000e-06	3.403800e-06
2.0	-1.323520e-06	-1.320000e-06	-1.079890e-06	6.753250e-07	1.820000e-06	3.444400e-06
3.0	-1.299690e-06	-1.270000e-06	-1.058030e-06	6.954840e-07	1.881000e-06	3.484780e-06
4.0	-1.275830e-06	-1.210000e-06	-1.035530e-06	7.157320e-07	1.940000e-06	3.524940e-06
5.0	-1.251940e-06	-1.160000e-06	-1.012390e-06	7.360700e-07	1.998000e-06	3.564880e-06
6.0	-1.228020e-06	-1.110000e-06	-9.886101e-07	7.564970e-07	2.055000e-06	3.604590e-06
7.0	-1.204070e-06	-1.060000e-06	-9.641930e-07	7.770140e-07	2.111000e-06	3.644080e-06
8.0	-1.180090e-06	-1.010000e-06	-9.391370e-07	7.976200e-07	2.165000e-06	3.683350e-06
9.0	-1.156080e-06	-9.670000e-07	-9.134420e-07	8.183160e-07	2.218000e-06	3.722390e-06
10.0	-1.132040e-06	-9.200000e-07	-8.871090e-07	8.391020e-07	2.270000e-06	3.761220e-06
11.0	-1.107970e-06	-8.750000e-07	-8.601360e-07	8.599770e-07	2.320000e-06	3.799820e-06
12.0	-1.083870e-06	-8.300000e-07	-8.325250e-07	8.809420e-07	2.369000e-06	3.838190e-06
13.0	-1.059740e-06	-7.860000e-07	-8.042750e-07	9.019960e-07	2.417000e-06	3.876350e-06
14.0	-1.035580e-06	-7.420000e-07	-7.753860e-07	9.231400e-07	2.464000e-06	3.914280e-06
15.0	-1.011390e-06	-7.000000e-07	-7.458580e-07	9.443740e-07	2.509000e-06	3.951990e-06
16.0	-9.871740e-07	-6.590000e-07	-7.156910e-07	9.656970e-07	2.554000e-06	3.989480e-06
17.0	-9.629240e-07	-6.180000e-07	-6.848860e-07	9.871100e-07	2.597000e-06	4.026740e-06
18.0	-9.386430e-07	-5.790000e-07	-6.534410e-07	1.008610e-06	2.638000e-06	4.063780e-06
19.0	-9.143330e-07	-5.400000e-07	-6.213580e-07	1.030200e-06	2.679000e-06	4.100600e-06
20.0	-8.899930e-07	-5.020000e-07	-5.886360e-07	1.051890e-06	2.718000e-06	4.137200e-06

21.0 -8.656230e-07 -4.650000e-07 -5.552750e-07 1.073660e-06 2.756000e-06 4.173570e-06  
 22.0 -8.412220e-07 -4.290000e-07 -5.212760e-07 1.095520e-06 2.792000e-06 4.209720e-06  
 23.0 -8.167920e-07 -3.930000e-07 -4.866370e-07 1.117470e-06 2.827000e-06 4.245650e-06  
 24.0 -7.923310e-07 -3.590000e-07 -4.513600e-07 1.139510e-06 2.861000e-06 4.281360e-06  
 25.0 -7.678410e-07 -3.250000e-07 -4.154430e-07 1.161640e-06 2.894000e-06 4.316840e-06  
 26.0 -7.433200e-07 -2.930000e-07 -3.788880e-07 1.183860e-06 2.926000e-06 4.352100e-06  
 27.0 -7.187700e-07 -2.610000e-07 -3.416940e-07 1.206170e-06 2.956000e-06 4.387140e-06  
 28.0 -6.941890e-07 -2.300000e-07 -3.038620e-07 1.228560e-06 2.985000e-06 4.421960e-06  
 29.0 -6.695780e-07 -2.000000e-07 -2.653900e-07 1.251050e-06 3.013000e-06 4.456550e-06  
 30.0 -6.449370e-07 -1.710000e-07 -2.262790e-07 1.273630e-06 3.039000e-06 4.490920e-06  
 31.0 -6.202660e-07 -1.420000e-07 -1.865300e-07 1.296300e-06 3.064000e-06 4.525070e-06  
 32.0 -5.955650e-07 -1.150000e-07 -1.461420e-07 1.319050e-06 3.088000e-06 4.558990e-06  
 33.0 -5.708340e-07 -8.830000e-08 -1.051150e-07 1.341900e-06 3.111000e-06 4.592690e-06  
 34.0 -5.460730e-07 -6.260000e-08 -6.344930e-08 1.364840e-06 3.132000e-06 4.626170e-06  
 35.0 -5.212820e-07 -3.770000e-08 -2.114470e-08 1.387860e-06 3.153000e-06 4.659430e-06  
 36.0 -4.964610e-07 -1.380000e-08 2.179880e-08 1.410980e-06 3.171000e-06 4.692460e-06  
 37.0 -4.716100e-07 9.340000e-09 6.538120e-08 1.434180e-06 3.189000e-06 4.725270e-06  
 38.0 -4.467280e-07 3.160000e-08 1.096020e-07 1.457480e-06 3.205000e-06 4.757860e-06  
 39.0 -4.218170e-07 5.290000e-08 1.544620e-07 1.480860e-06 3.221000e-06 4.790230e-06  
 40.0 -3.968760e-07 7.340000e-08 1.999610e-07 1.504330e-06 3.234000e-06 4.822370e-06  
 41.0 -3.719040e-07 9.300000e-08 2.460990e-07 1.527900e-06 3.247000e-06 4.854290e-06  
 42.0 -3.469030e-07 1.120000e-07 2.928750e-07 1.551550e-06 3.258000e-06 4.885990e-06  
 43.0 -3.218710e-07 1.300000e-07 3.402910e-07 1.575290e-06 3.268000e-06 4.917470e-06  
 44.0 -2.968090e-07 1.470000e-07 3.883450e-07 1.599120e-06 3.277000e-06 4.948720e-06  
 45.0 -2.717170e-07 1.630000e-07 4.370380e-07 1.623050e-06 3.284000e-06 4.979750e-06

Temp (°C)	23 GHz V		
	Low Gain	Nom Gain	High Gain
-10.000000	2.467000e-06	2.973000e-06	5.915010e-06
-9.000000	2.351000e-06	2.924000e-06	5.918900e-06
-8.000000	2.239980e-06	2.876000e-06	5.920720e-06
-7.000000	2.133950e-06	2.829000e-06	5.920450e-06
-6.000000	2.032910e-06	2.782000e-06	5.918110e-06
-5.000000	1.936850e-06	2.736000e-06	5.913700e-06
-4.000000	1.845790e-06	2.691000e-06	5.907210e-06
-3.000000	1.759700e-06	2.647000e-06	5.898640e-06
-2.000000	1.678610e-06	2.603000e-06	5.888000e-06
-1.000000	1.602500e-06	2.561000e-06	5.875280e-06
0.000000	1.531390e-06	2.519000e-06	5.860490e-06
1.000000	1.465250e-06	2.477000e-06	5.843620e-06
2.000000	1.404110e-06	2.437000e-06	5.824670e-06
3.000000	1.347950e-06	2.397000e-06	5.803650e-06
4.000000	1.296780e-06	2.358000e-06	5.780550e-06
5.000000	1.250600e-06	2.319000e-06	5.755380e-06
6.000000	1.209410e-06	2.282000e-06	5.728130e-06
7.000000	1.173200e-06	2.245000e-06	5.698810e-06
8.000000	1.141980e-06	2.209000e-06	5.667410e-06

9.000000 1.115740e-06 2.174000e-06 5.633930e-06  
 10.000000 1.094500e-06 2.139000e-06 5.598380e-06  
 11.000000 1.078240e-06 2.105000e-06 5.560750e-06  
 12.000000 1.066970e-06 2.072000e-06 5.521050e-06  
 13.000000 1.060680e-06 2.040000e-06 5.479270e-06  
 14.000000 1.059390e-06 2.008000e-06 5.435420e-06  
 15.000000 1.063080e-06 1.977000e-06 5.389490e-06  
 16.000000 1.071760e-06 1.947000e-06 5.341480e-06  
 17.000000 1.085420e-06 1.918000e-06 5.291400e-06  
 18.000000 1.104070e-06 1.889000e-06 5.239240e-06  
 19.000000 1.127720e-06 1.861000e-06 5.185010e-06  
 20.000000 1.156340e-06 1.834000e-06 5.128700e-06  
 21.000000 1.189960e-06 1.808000e-06 5.070310e-06  
 22.000000 1.228560e-06 1.782000e-06 5.009850e-06  
 23.000000 1.272150e-06 1.757000e-06 4.947310e-06  
 24.000000 1.320730e-06 1.733000e-06 4.882700e-06  
 25.000000 1.374290e-06 1.710000e-06 4.816010e-06  
 26.000000 1.432840e-06 1.687000e-06 4.747250e-06  
 27.000000 1.496380e-06 1.665000e-06 4.676410e-06  
 28.000000 1.564900e-06 1.644000e-06 4.603490e-06  
 29.000000 1.638420e-06 1.624000e-06 4.528500e-06  
 30.000000 1.716920e-06 1.604000e-06 4.451430e-06  
 31.000000 1.800410e-06 1.585000e-06 4.372290e-06  
 32.000000 1.888880e-06 1.567000e-06 4.291070e-06  
 33.000000 1.982340e-06 1.550000e-06 4.207780e-06  
 34.000000 2.080790e-06 1.533000e-06 4.122410e-06  
 35.000000 2.184230e-06 1.517000e-06 4.034960e-06  
 36.000000 2.292660e-06 1.502000e-06 3.945440e-06  
 37.000000 2.406070e-06 1.488000e-06 3.853840e-06  
 38.000000 2.524470e-06 1.474000e-06 3.760170e-06  
 39.000000 2.647850e-06 1.461000e-06 3.664420e-06  
 40.000000 2.776230e-06 1.449000e-06 3.566590e-06  
 41.000000 2.909590e-06 1.438000e-06 3.466690e-06  
 42.000000 3.047940e-06 1.427000e-06 3.364720e-06  
 43.000000 3.191270e-06 1.417000e-06 3.260660e-06  
 44.000000 3.339600e-06 1.408000e-06 3.154540e-06  
 45.000000 3.492910e-06 1.400000e-06 3.046330e-06

Temp (°C)	36 GHz V			36 GHz H		
	Low Gain	Nom Gain	High Gain	Low Gain	Nom Gain	High Gain
-10.0	-2.635890e-05	-3.163000e-05	-2.800700e-05	-2.322100e-05	-2.965000e-05	-2.593830e-05
-9.0	-2.612630e-05	-3.140000e-05	-2.758510e-05	-2.307380e-05	-2.945000e-05	-2.545650e-05
-8.0	-2.589420e-05	-3.117000e-05	-2.717110e-05	-2.292530e-05	-2.925000e-05	-2.498570e-05
-7.0	-2.566250e-05	-3.094000e-05	-2.676480e-05	-2.277530e-05	-2.904000e-05	-2.452580e-05
-6.0	-2.543130e-05	-3.071000e-05	-2.636640e-05	-2.262380e-05	-2.884000e-05	-2.407700e-05
-5.0	-2.520050e-05	-3.048000e-05	-2.597580e-05	-2.247090e-05	-2.863000e-05	-2.363910e-05
-4.0	-2.497020e-05	-3.025000e-05	-2.559310e-05	-2.231650e-05	-2.842000e-05	-2.321220e-05

-3.0 -2.474030e-05 -3.001000e-05 -2.521810e-05 -2.216070e-05 -2.821000e-05 -2.279630e-05  
 -2.0 -2.451080e-05 -2.977000e-05 -2.485100e-05 -2.200350e-05 -2.800000e-05 -2.239140e-05  
 -1.0 -2.428180e-05 -2.954000e-05 -2.449170e-05 -2.184480e-05 -2.779000e-05 -2.199750e-05  
 0.0 -2.405330e-05 -2.930000e-05 -2.414020e-05 -2.168470e-05 -2.757000e-05 -2.161450e-05  
 1.0 -2.382510e-05 -2.906000e-05 -2.379650e-05 -2.152310e-05 -2.736000e-05 -2.124250e-05  
 2.0 -2.359750e-05 -2.881000e-05 -2.346060e-05 -2.136010e-05 -2.714000e-05 -2.088150e-05  
 3.0 -2.337020e-05 -2.857000e-05 -2.313260e-05 -2.119560e-05 -2.693000e-05 -2.053150e-05  
 4.0 -2.314340e-05 -2.833000e-05 -2.281240e-05 -2.102970e-05 -2.671000e-05 -2.019250e-05  
 5.0 -2.291710e-05 -2.808000e-05 -2.250000e-05 -2.086240e-05 -2.649000e-05 -1.986450e-05  
 6.0 -2.269120e-05 -2.783000e-05 -2.219540e-05 -2.069360e-05 -2.627000e-05 -1.954740e-05  
 7.0 -2.246570e-05 -2.758000e-05 -2.189860e-05 -2.052330e-05 -2.604000e-05 -1.924140e-05  
 8.0 -2.224070e-05 -2.733000e-05 -2.160970e-05 -2.035160e-05 -2.582000e-05 -1.894630e-05  
 9.0 -2.201610e-05 -2.708000e-05 -2.132860e-05 -2.017850e-05 -2.559000e-05 -1.866220e-05  
 10.0 -2.179200e-05 -2.683000e-05 -2.105530e-05 -2.000390e-05 -2.537000e-05 -1.838910e-05  
 11.0 -2.156830e-05 -2.658000e-05 -2.078980e-05 -1.982790e-05 -2.514000e-05 -1.812690e-05  
 12.0 -2.134510e-05 -2.632000e-05 -2.053210e-05 -1.965050e-05 -2.491000e-05 -1.787580e-05  
 13.0 -2.112230e-05 -2.607000e-05 -2.028230e-05 -1.947150e-05 -2.468000e-05 -1.763560e-05  
 14.0 -2.089990e-05 -2.581000e-05 -2.004020e-05 -1.929120e-05 -2.445000e-05 -1.740650e-05  
 15.0 -2.067800e-05 -2.555000e-05 -1.980600e-05 -1.910940e-05 -2.422000e-05 -1.718830e-05  
 16.0 -2.045660e-05 -2.529000e-05 -1.957960e-05 -1.892610e-05 -2.399000e-05 -1.698100e-05  
 17.0 -2.023550e-05 -2.503000e-05 -1.936100e-05 -1.874150e-05 -2.375000e-05 -1.678480e-05  
 18.0 -2.001500e-05 -2.476000e-05 -1.915030e-05 -1.855530e-05 -2.351000e-05 -1.659960e-05  
 19.0 -1.979480e-05 -2.450000e-05 -1.894730e-05 -1.836780e-05 -2.328000e-05 -1.642530e-05  
 20.0 -1.957510e-05 -2.423000e-05 -1.875220e-05 -1.817870e-05 -2.304000e-05 -1.626200e-05  
 21.0 -1.935590e-05 -2.397000e-05 -1.856490e-05 -1.798830e-05 -2.280000e-05 -1.610970e-05  
 22.0 -1.913710e-05 -2.370000e-05 -1.838540e-05 -1.779640e-05 -2.256000e-05 -1.596840e-05  
 23.0 -1.891870e-05 -2.343000e-05 -1.821380e-05 -1.760300e-05 -2.232000e-05 -1.583810e-05  
 24.0 -1.870080e-05 -2.316000e-05 -1.804990e-05 -1.740820e-05 -2.207000e-05 -1.571880e-05  
 25.0 -1.848330e-05 -2.288000e-05 -1.789390e-05 -1.721200e-05 -2.183000e-05 -1.561040e-05  
 26.0 -1.826630e-05 -2.261000e-05 -1.774570e-05 -1.701430e-05 -2.158000e-05 -1.551300e-05  
 27.0 -1.804970e-05 -2.234000e-05 -1.760530e-05 -1.681510e-05 -2.133000e-05 -1.542660e-05  
 28.0 -1.783360e-05 -2.206000e-05 -1.747270e-05 -1.661460e-05 -2.108000e-05 -1.535120e-05  
 29.0 -1.761790e-05 -2.178000e-05 -1.734800e-05 -1.641250e-05 -2.083000e-05 -1.528680e-05  
 30.0 -1.740260e-05 -2.150000e-05 -1.723100e-05 -1.620910e-05 -2.058000e-05 -1.523340e-05  
 31.0 -1.718780e-05 -2.122000e-05 -1.712190e-05 -1.600420e-05 -2.033000e-05 -1.519090e-05  
 32.0 -1.697340e-05 -2.094000e-05 -1.702060e-05 -1.579780e-05 -2.008000e-05 -1.515950e-05  
 33.0 -1.675950e-05 -2.066000e-05 -1.692710e-05 -1.559000e-05 -1.982000e-05 -1.513900e-05  
 34.0 -1.654600e-05 -2.037000e-05 -1.684150e-05 -1.538080e-05 -1.957000e-05 -1.512950e-05  
 35.0 -1.633300e-05 -2.009000e-05 -1.676360e-05 -1.517010e-05 -1.931000e-05 -1.513100e-05  
 36.0 -1.612040e-05 -1.980000e-05 -1.669360e-05 -1.495790e-05 -1.905000e-05 -1.514340e-05  
 37.0 -1.590820e-05 -1.951000e-05 -1.663140e-05 -1.474440e-05 -1.879000e-05 -1.516690e-05  
 38.0 -1.569650e-05 -1.922000e-05 -1.657700e-05 -1.452930e-05 -1.853000e-05 -1.520130e-05  
 39.0 -1.548530e-05 -1.893000e-05 -1.653050e-05 -1.431290e-05 -1.827000e-05 -1.524670e-05  
 40.0 -1.527440e-05 -1.864000e-05 -1.649170e-05 -1.409500e-05 -1.800000e-05 -1.530310e-05  
 41.0 -1.506410e-05 -1.835000e-05 -1.646080e-05 -1.387560e-05 -1.774000e-05 -1.537050e-05  
 42.0 -1.485410e-05 -1.805000e-05 -1.643770e-05 -1.365480e-05 -1.747000e-05 -1.544890e-05  
 43.0 -1.464460e-05 -1.776000e-05 -1.642240e-05 -1.343260e-05 -1.720000e-05 -1.553820e-05

44.0 -1.443560e-05 -1.746000e-05 -1.641490e-05 -1.320890e-05 -1.694000e-05 -1.563860e-05  
45.0 -1.422700e-05 -1.716000e-05 -1.641530e-05 -1.298370e-05 -1.667000e-05 -1.574990e-05

Temp (°C)	89 GHz V			89 GHz H		
	Low Gain	Nom Gain	High Gain	Low Gain	Nom Gain	High Gain
-10.0	-2.184000e-05	-2.410000e-05	-1.565000e-05	-2.298000e-05	-2.940000e-05	-2.031000e-05
-9.0	-2.150000e-05	-2.397000e-05	-1.608000e-05	-2.273000e-05	-2.922000e-05	-2.056000e-05
-8.0	-2.116000e-05	-2.384000e-05	-1.650000e-05	-2.248000e-05	-2.902000e-05	-2.079000e-05
-7.0	-2.083000e-05	-2.371000e-05	-1.691000e-05	-2.224000e-05	-2.883000e-05	-2.101000e-05
-6.0	-2.051000e-05	-2.357000e-05	-1.729000e-05	-2.200000e-05	-2.863000e-05	-2.123000e-05
-5.0	-2.020000e-05	-2.344000e-05	-1.767000e-05	-2.177000e-05	-2.843000e-05	-2.143000e-05
-4.0	-1.989000e-05	-2.330000e-05	-1.802000e-05	-2.154000e-05	-2.823000e-05	-2.162000e-05
-3.0	-1.959000e-05	-2.316000e-05	-1.836000e-05	-2.132000e-05	-2.802000e-05	-2.180000e-05
-2.0	-1.930000e-05	-2.302000e-05	-1.869000e-05	-2.111000e-05	-2.781000e-05	-2.197000e-05
-1.0	-1.902000e-05	-2.287000e-05	-1.900000e-05	-2.090000e-05	-2.760000e-05	-2.213000e-05
0.0	-1.875000e-05	-2.273000e-05	-1.930000e-05	-2.070000e-05	-2.738000e-05	-2.228000e-05
1.0	-1.848000e-05	-2.258000e-05	-1.958000e-05	-2.050000e-05	-2.717000e-05	-2.242000e-05
2.0	-1.822000e-05	-2.243000e-05	-1.984000e-05	-2.030000e-05	-2.694000e-05	-2.255000e-05
3.0	-1.797000e-05	-2.228000e-05	-2.009000e-05	-2.012000e-05	-2.672000e-05	-2.267000e-05
4.0	-1.772000e-05	-2.213000e-05	-2.032000e-05	-1.994000e-05	-2.650000e-05	-2.277000e-05
5.0	-1.749000e-05	-2.198000e-05	-2.054000e-05	-1.976000e-05	-2.627000e-05	-2.287000e-05
6.0	-1.726000e-05	-2.183000e-05	-2.074000e-05	-1.959000e-05	-2.604000e-05	-2.296000e-05
7.0	-1.704000e-05	-2.167000e-05	-2.093000e-05	-1.943000e-05	-2.580000e-05	-2.303000e-05
8.0	-1.682000e-05	-2.151000e-05	-2.110000e-05	-1.927000e-05	-2.556000e-05	-2.310000e-05
9.0	-1.662000e-05	-2.135000e-05	-2.126000e-05	-1.911000e-05	-2.532000e-05	-2.316000e-05
10.0	-1.642000e-05	-2.119000e-05	-2.140000e-05	-1.897000e-05	-2.508000e-05	-2.320000e-05
11.0	-1.623000e-05	-2.103000e-05	-2.152000e-05	-1.882000e-05	-2.483000e-05	-2.323000e-05
12.0	-1.605000e-05	-2.086000e-05	-2.163000e-05	-1.869000e-05	-2.459000e-05	-2.326000e-05
13.0	-1.587000e-05	-2.070000e-05	-2.173000e-05	-1.856000e-05	-2.434000e-05	-2.327000e-05
14.0	-1.570000e-05	-2.053000e-05	-2.181000e-05	-1.843000e-05	-2.408000e-05	-2.327000e-05
15.0	-1.555000e-05	-2.036000e-05	-2.187000e-05	-1.831000e-05	-2.382000e-05	-2.327000e-05
16.0	-1.539000e-05	-2.019000e-05	-2.192000e-05	-1.820000e-05	-2.356000e-05	-2.325000e-05
17.0	-1.525000e-05	-2.002000e-05	-2.195000e-05	-1.809000e-05	-2.330000e-05	-2.322000e-05
18.0	-1.511000e-05	-1.984000e-05	-2.197000e-05	-1.799000e-05	-2.304000e-05	-2.318000e-05
19.0	-1.499000e-05	-1.967000e-05	-2.197000e-05	-1.789000e-05	-2.277000e-05	-2.313000e-05
20.0	-1.487000e-05	-1.949000e-05	-2.195000e-05	-1.780000e-05	-2.250000e-05	-2.307000e-05
21.0	-1.475000e-05	-1.931000e-05	-2.192000e-05	-1.771000e-05	-2.222000e-05	-2.300000e-05
22.0	-1.465000e-05	-1.913000e-05	-2.188000e-05	-1.763000e-05	-2.195000e-05	-2.292000e-05
23.0	-1.455000e-05	-1.895000e-05	-2.182000e-05	-1.756000e-05	-2.167000e-05	-2.283000e-05
24.0	-1.446000e-05	-1.876000e-05	-2.174000e-05	-1.749000e-05	-2.139000e-05	-2.272000e-05
25.0	-1.438000e-05	-1.858000e-05	-2.165000e-05	-1.742000e-05	-2.110000e-05	-2.261000e-05
26.0	-1.430000e-05	-1.839000e-05	-2.155000e-05	-1.736000e-05	-2.081000e-05	-2.249000e-05
27.0	-1.424000e-05	-1.820000e-05	-2.142000e-05	-1.731000e-05	-2.052000e-05	-2.235000e-05
28.0	-1.418000e-05	-1.801000e-05	-2.129000e-05	-1.727000e-05	-2.023000e-05	-2.221000e-05
29.0	-1.413000e-05	-1.782000e-05	-2.113000e-05	-1.722000e-05	-1.993000e-05	-2.206000e-05
30.0	-1.408000e-05	-1.762000e-05	-2.096000e-05	-1.719000e-05	-1.963000e-05	-2.189000e-05
31.0	-1.405000e-05	-1.743000e-05	-2.078000e-05	-1.716000e-05	-1.933000e-05	-2.172000e-05

32.0 -1.402000e-05 -1.723000e-05 -2.058000e-05 -1.713000e-05 -1.903000e-05 -2.153000e-05  
 33.0 -1.400000e-05 -1.703000e-05 -2.037000e-05 -1.711000e-05 -1.872000e-05 -2.133000e-05  
 34.0 -1.399000e-05 -1.683000e-05 -2.013000e-05 -1.710000e-05 -1.841000e-05 -2.113000e-05  
 35.0 -1.398000e-05 -1.663000e-05 -1.989000e-05 -1.709000e-05 -1.810000e-05 -2.091000e-05  
 36.0 -1.399000e-05 -1.642000e-05 -1.963000e-05 -1.709000e-05 -1.778000e-05 -2.068000e-05  
 37.0 -1.400000e-05 -1.622000e-05 -1.935000e-05 -1.709000e-05 -1.746000e-05 -2.044000e-05  
 38.0 -1.402000e-05 -1.601000e-05 -1.906000e-05 -1.710000e-05 -1.714000e-05 -2.019000e-05  
 39.0 -1.404000e-05 -1.580000e-05 -1.875000e-05 -1.712000e-05 -1.682000e-05 -1.993000e-05  
 40.0 -1.408000e-05 -1.559000e-05 -1.843000e-05 -1.714000e-05 -1.649000e-05 -1.966000e-05  
 41.0 -1.412000e-05 -1.538000e-05 -1.809000e-05 -1.716000e-05 -1.616000e-05 -1.938000e-05  
 42.0 -1.417000e-05 -1.516000e-05 -1.774000e-05 -1.719000e-05 -1.583000e-05 -1.909000e-05  
 43.0 -1.422000e-05 -1.495000e-05 -1.737000e-05 -1.723000e-05 -1.549000e-05 -1.879000e-05  
 44.0 -1.429000e-05 -1.473000e-05 -1.698000e-05 -1.727000e-05 -1.515000e-05 -1.848000e-05  
 45.0 -1.436000e-05 -1.451000e-05 -1.658000e-05 -1.732000e-05 -1.481000e-05 -1.816000e-05

Temp (°C)	166 GHz V			166 GHz H		
	Low Gain	Nom Gain	High Gain	Low Gain	Nom Gain	High Gain
-10.0	-1.902190e-05	-2.344340e-05	-2.142110e-05	-1.283290e-05	-1.617280e-05	-1.431040e-05
-9.0	-1.891470e-05	-2.255690e-05	-2.103910e-05	-1.295210e-05	-1.566520e-05	-1.422220e-05
-8.0	-1.880250e-05	-2.169830e-05	-2.066560e-05	-1.306150e-05	-1.516990e-05	-1.413080e-05
-7.0	-1.868560e-05	-2.086770e-05	-2.030060e-05	-1.316100e-05	-1.468680e-05	-1.403630e-05
-6.0	-1.856370e-05	-2.006510e-05	-1.994420e-05	-1.325080e-05	-1.421600e-05	-1.393860e-05
-5.0	-1.843700e-05	-1.929040e-05	-1.959630e-05	-1.333080e-05	-1.375740e-05	-1.383770e-05
-4.0	-1.830550e-05	-1.854370e-05	-1.925700e-05	-1.340090e-05	-1.331100e-05	-1.373370e-05
-3.0	-1.816910e-05	-1.782500e-05	-1.892620e-05	-1.346130e-05	-1.287680e-05	-1.362650e-05
-2.0	-1.802790e-05	-1.713420e-05	-1.860400e-05	-1.351180e-05	-1.245490e-05	-1.351620e-05
-1.0	-1.788180e-05	-1.647140e-05	-1.829030e-05	-1.355250e-05	-1.204520e-05	-1.340260e-05
0.0	-1.773080e-05	-1.583660e-05	-1.798510e-05	-1.358340e-05	-1.164780e-05	-1.328590e-05
1.0	-1.757510e-05	-1.522970e-05	-1.768850e-05	-1.360460e-05	-1.126260e-05	-1.316610e-05
2.0	-1.741440e-05	-1.465080e-05	-1.740040e-05	-1.361590e-05	-1.088960e-05	-1.304310e-05
3.0	-1.724890e-05	-1.409990e-05	-1.712090e-05	-1.361740e-05	-1.052880e-05	-1.291690e-05
4.0	-1.707860e-05	-1.357690e-05	-1.684990e-05	-1.360910e-05	-1.018030e-05	-1.278750e-05
5.0	-1.690340e-05	-1.308190e-05	-1.658750e-05	-1.359090e-05	-9.843960e-06	-1.265500e-05
6.0	-1.672330e-05	-1.261490e-05	-1.633360e-05	-1.356300e-05	-9.519880e-06	-1.251930e-05
7.0	-1.653840e-05	-1.217590e-05	-1.608820e-05	-1.352530e-05	-9.208040e-06	-1.238050e-05
8.0	-1.634860e-05	-1.176480e-05	-1.585140e-05	-1.347770e-05	-8.908440e-06	-1.223850e-05
9.0	-1.615400e-05	-1.138170e-05	-1.562310e-05	-1.342040e-05	-8.621060e-06	-1.209330e-05
10.0	-1.595460e-05	-1.102650e-05	-1.540340e-05	-1.335320e-05	-8.345910e-06	-1.194490e-05
11.0	-1.575020e-05	-1.069930e-05	-1.519220e-05	-1.327630e-05	-8.083000e-06	-1.179340e-05
12.0	-1.554110e-05	-1.040010e-05	-1.498960e-05	-1.318950e-05	-7.832310e-06	-1.163870e-05
13.0	-1.532710e-05	-1.012890e-05	-1.479550e-05	-1.309290e-05	-7.593860e-06	-1.148090e-05
14.0	-1.510820e-05	-9.885630e-06	-1.460990e-05	-1.298660e-05	-7.367640e-06	-1.131990e-05
15.0	-1.488450e-05	-9.670330e-06	-1.443290e-05	-1.287040e-05	-7.153650e-06	-1.115570e-05
16.0	-1.465590e-05	-9.483000e-06	-1.426440e-05	-1.274440e-05	-6.951890e-06	-1.098830e-05
17.0	-1.442250e-05	-9.323630e-06	-1.410450e-05	-1.260860e-05	-6.762360e-06	-1.081780e-05
18.0	-1.418420e-05	-9.192230e-06	-1.395310e-05	-1.246290e-05	-6.585060e-06	-1.064410e-05
19.0	-1.394110e-05	-9.088810e-06	-1.381030e-05	-1.230750e-05	-6.420000e-06	-1.046730e-05

20.0 -1.369310e-05 -9.013350e-06 -1.367600e-05 -1.214230e-05 -6.267160e-06 -1.028730e-05  
 21.0 -1.344020e-05 -8.965850e-06 -1.355020e-05 -1.196720e-05 -6.126560e-06 -1.010410e-05  
 22.0 -1.318260e-05 -8.946330e-06 -1.343300e-05 -1.178240e-05 -5.998190e-06 -9.917770e-06  
 23.0 -1.292000e-05 -8.954780e-06 -1.332430e-05 -1.158770e-05 -5.882040e-06 -9.728260e-06  
 24.0 -1.265260e-05 -8.991190e-06 -1.322420e-05 -1.138330e-05 -5.778130e-06 -9.535590e-06  
 25.0 -1.238040e-05 -9.055580e-06 -1.313260e-05 -1.116900e-05 -5.686460e-06 -9.339750e-06  
 26.0 -1.210330e-05 -9.147930e-06 -1.304960e-05 -1.094490e-05 -5.607010e-06 -9.140740e-06  
 27.0 -1.182130e-05 -9.268250e-06 -1.297510e-05 -1.071110e-05 -5.539790e-06 -8.938570e-06  
 28.0 -1.153450e-05 -9.416540e-06 -1.290910e-05 -1.046740e-05 -5.484810e-06 -8.733230e-06  
 29.0 -1.124290e-05 -9.592790e-06 -1.285170e-05 -1.021390e-05 -5.442050e-06 -8.524730e-06  
 30.0 -1.094640e-05 -9.797020e-06 -1.280280e-05 -9.950570e-06 -5.411530e-06 -8.313060e-06  
 31.0 -1.064500e-05 -1.002920e-05 -1.276250e-05 -9.677450e-06 -5.393240e-06 -8.098220e-06  
 32.0 -1.033880e-05 -1.028940e-05 -1.273070e-05 -9.394530e-06 -5.387180e-06 -7.880220e-06  
 33.0 -1.002780e-05 -1.057750e-05 -1.270750e-05 -9.101800e-06 -5.393350e-06 -7.659050e-06  
 34.0 -9.711870e-06 -1.089360e-05 -1.269280e-05 -8.799270e-06 -5.411750e-06 -7.434720e-06  
 35.0 -9.391110e-06 -1.123770e-05 -1.268660e-05 -8.486920e-06 -5.442380e-06 -7.207220e-06  
 36.0 -9.065500e-06 -1.160970e-05 -1.268900e-05 -8.164770e-06 -5.485250e-06 -6.976550e-06  
 37.0 -8.735030e-06 -1.200970e-05 -1.269990e-05 -7.832810e-06 -5.540340e-06 -6.742720e-06  
 38.0 -8.399710e-06 -1.243770e-05 -1.271940e-05 -7.491040e-06 -5.607670e-06 -6.505720e-06  
 39.0 -8.059550e-06 -1.289360e-05 -1.274740e-05 -7.139470e-06 -5.687230e-06 -6.265550e-06  
 40.0 -7.714520e-06 -1.337750e-05 -1.278400e-05 -6.778090e-06 -5.779020e-06 -6.022220e-06  
 41.0 -7.364650e-06 -1.388940e-05 -1.282910e-05 -6.406900e-06 -5.883040e-06 -5.775730e-06  
 42.0 -7.009930e-06 -1.442930e-05 -1.288270e-05 -6.025900e-06 -5.999290e-06 -5.526060e-06  
 43.0 -6.650350e-06 -1.499710e-05 -1.294490e-05 -5.635090e-06 -6.127770e-06 -5.273240e-06  
 44.0 -6.285920e-06 -1.559290e-05 -1.301570e-05 -5.234480e-06 -6.268490e-06 -5.017240e-06  
 45.0 -5.916640e-06 -1.621660e-05 -1.309490e-05 -4.824060e-06 -6.421430e-06 -4.758080e-06

Temp (°C)	183± 3 GHz V			183 ±7 GHz H		
	Low Gain	Nom Gain	High Gain	Low Gain	Nom Gain	High Gain
-10.0	-3.020000e-05	-1.893000e-05	-2.557000e-05	-2.546170e-05	-2.235580e-05	-2.983840e-05
-9.0	-2.994000e-05	-1.924000e-05	-2.504000e-05	-2.519400e-05	-2.237860e-05	-2.928050e-05
-8.0	-2.969000e-05	-1.955000e-05	-2.452000e-05	-2.492760e-05	-2.239260e-05	-2.873320e-05
-7.0	-2.943000e-05	-1.983000e-05	-2.401000e-05	-2.466260e-05	-2.239780e-05	-2.819660e-05
-6.0	-2.918000e-05	-2.010000e-05	-2.352000e-05	-2.439880e-05	-2.239410e-05	-2.767050e-05
-5.0	-2.892000e-05	-2.036000e-05	-2.304000e-05	-2.413640e-05	-2.238160e-05	-2.715510e-05
-4.0	-2.867000e-05	-2.060000e-05	-2.258000e-05	-2.387530e-05	-2.236030e-05	-2.665030e-05
-3.0	-2.841000e-05	-2.082000e-05	-2.212000e-05	-2.361560e-05	-2.233020e-05	-2.615610e-05
-2.0	-2.816000e-05	-2.103000e-05	-2.168000e-05	-2.335710e-05	-2.229120e-05	-2.567260e-05
-1.0	-2.791000e-05	-2.123000e-05	-2.125000e-05	-2.310000e-05	-2.224350e-05	-2.519970e-05
0.0	-2.765000e-05	-2.141000e-05	-2.084000e-05	-2.284420e-05	-2.218690e-05	-2.473740e-05
1.0	-2.740000e-05	-2.157000e-05	-2.044000e-05	-2.258970e-05	-2.212150e-05	-2.428570e-05
2.0	-2.715000e-05	-2.172000e-05	-2.005000e-05	-2.233650e-05	-2.204720e-05	-2.384460e-05
3.0	-2.690000e-05	-2.185000e-05	-1.967000e-05	-2.208460e-05	-2.196420e-05	-2.341420e-05
4.0	-2.665000e-05	-2.197000e-05	-1.930000e-05	-2.183410e-05	-2.187230e-05	-2.299440e-05
5.0	-2.639000e-05	-2.207000e-05	-1.895000e-05	-2.158490e-05	-2.177160e-05	-2.258520e-05
6.0	-2.614000e-05	-2.216000e-05	-1.862000e-05	-2.133700e-05	-2.166210e-05	-2.218670e-05
7.0	-2.589000e-05	-2.223000e-05	-1.829000e-05	-2.109040e-05	-2.154380e-05	-2.179870e-05

8.0 -2.564000e-05 -2.229000e-05 -1.798000e-05 -2.084510e-05 -2.141660e-05 -2.142140e-05  
9.0 -2.539000e-05 -2.233000e-05 -1.768000e-05 -2.060120e-05 -2.128070e-05 -2.105470e-05  
10.0 -2.514000e-05 -2.236000e-05 -1.739000e-05 -2.035860e-05 -2.113590e-05 -2.069870e-05  
11.0 -2.490000e-05 -2.237000e-05 -1.712000e-05 -2.011730e-05 -2.098230e-05 -2.035320e-05  
12.0 -2.465000e-05 -2.236000e-05 -1.685000e-05 -1.987730e-05 -2.081990e-05 -2.001840e-05  
13.0 -2.440000e-05 -2.234000e-05 -1.661000e-05 -1.963860e-05 -2.064860e-05 -1.969420e-05  
14.0 -2.415000e-05 -2.231000e-05 -1.637000e-05 -1.940130e-05 -2.046850e-05 -1.938070e-05  
15.0 -2.390000e-05 -2.226000e-05 -1.615000e-05 -1.916520e-05 -2.027960e-05 -1.907770e-05  
16.0 -2.366000e-05 -2.219000e-05 -1.594000e-05 -1.893050e-05 -2.008190e-05 -1.878540e-05  
17.0 -2.341000e-05 -2.211000e-05 -1.574000e-05 -1.869710e-05 -1.987540e-05 -1.850370e-05  
18.0 -2.316000e-05 -2.201000e-05 -1.555000e-05 -1.846500e-05 -1.966010e-05 -1.823270e-05  
19.0 -2.292000e-05 -2.190000e-05 -1.538000e-05 -1.823430e-05 -1.943590e-05 -1.797220e-05  
20.0 -2.267000e-05 -2.177000e-05 -1.522000e-05 -1.800490e-05 -1.920290e-05 -1.772240e-05  
21.0 -2.243000e-05 -2.163000e-05 -1.508000e-05 -1.777670e-05 -1.896110e-05 -1.748320e-05  
22.0 -2.218000e-05 -2.147000e-05 -1.494000e-05 -1.754990e-05 -1.871050e-05 -1.725460e-05  
23.0 -2.194000e-05 -2.130000e-05 -1.482000e-05 -1.732450e-05 -1.845100e-05 -1.703670e-05  
24.0 -2.169000e-05 -2.111000e-05 -1.472000e-05 -1.710030e-05 -1.818270e-05 -1.682940e-05  
25.0 -2.145000e-05 -2.091000e-05 -1.462000e-05 -1.687750e-05 -1.790570e-05 -1.663270e-05  
26.0 -2.120000e-05 -2.069000e-05 -1.454000e-05 -1.665590e-05 -1.761970e-05 -1.644660e-05  
27.0 -2.096000e-05 -2.046000e-05 -1.447000e-05 -1.643570e-05 -1.732500e-05 -1.627120e-05  
28.0 -2.072000e-05 -2.021000e-05 -1.441000e-05 -1.621680e-05 -1.702150e-05 -1.610630e-05  
29.0 -2.048000e-05 -1.994000e-05 -1.437000e-05 -1.599930e-05 -1.670910e-05 -1.595210e-05  
30.0 -2.023000e-05 -1.966000e-05 -1.434000e-05 -1.578300e-05 -1.638790e-05 -1.580850e-05  
31.0 -1.999000e-05 -1.937000e-05 -1.432000e-05 -1.556810e-05 -1.605790e-05 -1.567560e-05  
32.0 -1.975000e-05 -1.906000e-05 -1.432000e-05 -1.535450e-05 -1.571910e-05 -1.555330e-05  
33.0 -1.951000e-05 -1.873000e-05 -1.432000e-05 -1.514220e-05 -1.537140e-05 -1.544160e-05  
34.0 -1.927000e-05 -1.839000e-05 -1.435000e-05 -1.493120e-05 -1.501490e-05 -1.534050e-05  
35.0 -1.903000e-05 -1.803000e-05 -1.438000e-05 -1.472160e-05 -1.464960e-05 -1.525000e-05  
36.0 -1.879000e-05 -1.766000e-05 -1.442000e-05 -1.451320e-05 -1.427550e-05 -1.517020e-05  
37.0 -1.855000e-05 -1.727000e-05 -1.448000e-05 -1.430620e-05 -1.389260e-05 -1.510100e-05  
38.0 -1.831000e-05 -1.687000e-05 -1.456000e-05 -1.410050e-05 -1.350090e-05 -1.504240e-05  
39.0 -1.807000e-05 -1.645000e-05 -1.464000e-05 -1.389620e-05 -1.310030e-05 -1.499440e-05  
40.0 -1.783000e-05 -1.602000e-05 -1.474000e-05 -1.369310e-05 -1.269090e-05 -1.495710e-05  
41.0 -1.759000e-05 -1.557000e-05 -1.485000e-05 -1.349140e-05 -1.227270e-05 -1.493040e-05  
42.0 -1.736000e-05 -1.511000e-05 -1.497000e-05 -1.329090e-05 -1.184560e-05 -1.491430e-05  
43.0 -1.712000e-05 -1.463000e-05 -1.511000e-05 -1.309180e-05 -1.140980e-05 -1.490880e-05  
44.0 -1.688000e-05 -1.413000e-05 -1.526000e-05 -1.289410e-05 -1.096510e-05 -1.491400e-05  
45.0 -1.664000e-05 -1.362000e-05 -1.542000e-05 -1.269760e-05 -1.051160e-05 -1.492980e-05

## **6. APPENDIX B. COLD BEAM POINTING VECTORS**

10 GHZ

Samp#	Rotate Angle	pointing theta	pointing phi	unit vector xhat	unit vector yhat	unit vector zhat
342	165.234894	70.396698	-100.428001	-0.170529	-0.926472	0.335514
343	165.926102	70.930199	-101.105003	-0.182057	-0.927418	0.326728
344	166.617294	71.445297	-101.783997	-0.193626	-0.928034	0.318217
345	167.308502	71.941803	-102.463997	-0.205214	-0.928329	0.309989
346	167.999695	72.419701	-103.143997	-0.216797	-0.928314	0.302048
347	168.690903	72.879097	-103.825996	-0.228402	-0.927990	0.294394
348	169.382095	73.320000	-104.509003	-0.240008	-0.927367	0.287030
349	170.073303	73.742302	-105.193001	-0.251609	-0.926453	0.279961
350	170.764496	74.146103	-105.876999	-0.263183	-0.925258	0.273188
351	171.455704	74.531303	-106.563004	-0.274759	-0.923781	0.266714
352	172.146896	74.898003	-107.250000	-0.286316	-0.922032	0.260539
353	172.838104	75.246101	-107.938004	-0.297848	-0.920017	0.254668
354	173.529297	75.575699	-108.626999	-0.309352	-0.917742	0.249100
355	174.220505	75.886803	-109.317001	-0.320824	-0.915213	0.243837
356	174.911697	76.179298	-110.008003	-0.332260	-0.912436	0.238883
357	175.602905	76.453201	-110.700996	-0.343671	-0.909408	0.234237
358	176.294098	76.708603	-111.393997	-0.355022	-0.906149	0.229900
359	176.985306	76.945503	-112.087997	-0.366325	-0.902655	0.225874
360	177.676498	77.163803	-112.782997	-0.377578	-0.898933	0.222160
361	178.367706	77.363602	-113.480003	-0.388791	-0.894978	0.218758
362	179.058899	77.544800	-114.177002	-0.399931	-0.890810	0.215670
363	179.750107	77.707497	-114.875999	-0.411024	-0.886417	0.212896
364	180.441299	77.851700	-115.574997	-0.422038	-0.881817	0.210435
365	181.132507	77.977303	-116.276001	-0.432998	-0.876999	0.208291
366	181.823700	78.084297	-116.976997	-0.443871	-0.871982	0.206463
367	182.514893	78.172798	-117.680000	-0.454683	-0.866751	0.204951
368	183.206100	78.242798	-118.384003	-0.465417	-0.861319	0.203754

18 GHZ

Samp#	Rotate Angle	pointing theta	pointing phi	unit vector xhat	unit vector yhat	unit vector zhat
390	192.786896	67.668503	-115.852997	-0.403382	-0.832415	0.379957
391	193.478104	67.879501	-116.431999	-0.412393	-0.829544	0.376548
392	194.169296	68.073799	-117.016998	-0.421419	-0.826424	0.373403
393	194.860504	68.251602	-117.606003	-0.430427	-0.823071	0.370522
394	195.551697	68.412804	-118.199997	-0.439428	-0.819480	0.367907
395	196.242905	68.557404	-118.797997	-0.448402	-0.815661	0.365558
396	196.934097	68.685402	-119.402000	-0.457376	-0.811598	0.363477
397	197.625305	68.796799	-120.009003	-0.466300	-0.807318	0.361665
398	198.316498	68.891602	-120.622002	-0.475215	-0.802797	0.360121
399	199.007706	68.969902	-121.238998	-0.484087	-0.798054	0.358845
400	199.698898	69.031502	-121.861000	-0.492926	-0.793079	0.357841

401 200.390106 69.076599 -122.487000 -0.501712 -0.787884 0.357105  
 402 201.081299 69.105003 -123.119003 -0.510469 -0.782450 0.356641  
 403 201.772507 69.116898 -123.753998 -0.519150 -0.776807 0.356447  
 404 202.463699 69.112198 -124.394997 -0.527792 -0.770926 0.356523  
 405 203.154907 69.090797 -125.040001 -0.536360 -0.764827 0.356871  
 406 203.846100 69.052902 -125.690002 -0.544865 -0.758502 0.357488  
 407 204.537292 68.998398 -126.344002 -0.553285 -0.751959 0.358376  
 408 205.228500 68.927399 -127.002998 -0.561630 -0.745191 0.359532  
 409 205.919693 68.839699 -127.667000 -0.569891 -0.738196 0.360959  
 410 206.610901 68.735397 -128.335999 -0.578063 -0.730975 0.362655

### 23 GHZ

Samp#	Rotate	pointing	pointing	unit vector		
	Angle	theta	phi	xhat	yhat	xhat
388	191.431305	67.178902	-114.904999	-0.388174	-0.835999	0.387848
389	192.122498	67.422501	-115.486000	-0.397337	-0.833502	0.383926
390	192.813705	67.648697	-116.070000	-0.406474	-0.830764	0.380277
391	193.504898	67.857597	-116.656998	-0.415583	-0.827790	0.376901
392	194.196106	68.049103	-117.246002	-0.424645	-0.824590	0.373803
393	194.887299	68.223198	-117.837997	-0.433671	-0.821159	0.370982
394	195.578506	68.379997	-118.432999	-0.442656	-0.817501	0.368439
395	196.269699	68.519402	-119.029999	-0.451584	-0.813626	0.366175
396	196.960907	68.641403	-119.629997	-0.460463	-0.809529	0.364192
397	197.652100	68.746101	-120.232002	-0.469278	-0.805220	0.362489
398	198.343307	68.833397	-120.836998	-0.478037	-0.800694	0.361068
399	199.034500	68.903297	-121.445000	-0.486735	-0.795952	0.359930
400	199.725693	68.955902	-122.056000	-0.495371	-0.790996	0.359072
401	200.416901	68.991096	-122.668999	-0.503924	-0.785837	0.358498
402	201.108093	69.009003	-123.285004	-0.512405	-0.780467	0.358206
403	201.799301	69.009499	-123.903000	-0.520795	-0.774898	0.358197
404	202.490494	68.992599	-124.524002	-0.529103	-0.769121	0.358472
405	203.181702	68.958397	-125.147003	-0.537312	-0.763148	0.359029
406	203.872894	68.906799	-125.774002	-0.545442	-0.756960	0.359868
407	204.564102	68.837799	-126.403000	-0.553461	-0.750577	0.360991
408	205.255295	68.751503	-127.033997	-0.561365	-0.744002	0.362395

### 36 GHZ

Samp#	Rotate	pointing	pointing	unit vector		
	Angle	theta	phi	xhat	yhat	xhat
437	218.862000	65.356300	-116.477997	-0.405270	-0.813570	0.416966
438	219.553207	65.578697	-117.061996	-0.414275	-0.810832	0.413434
439	220.244400	65.783096	-117.648003	-0.423227	-0.807854	0.410183
440	220.935593	65.969498	-118.236000	-0.432124	-0.804640	0.407213
441	221.626801	66.137901	-118.827003	-0.440976	-0.801186	0.404526
442	222.317993	66.288200	-119.419998	-0.449764	-0.797501	0.402125
443	223.009201	66.420601	-120.014000	-0.458471	-0.793598	0.400008
444	223.700394	66.534897	-120.611000	-0.467121	-0.789463	0.398178

445 224.391602 66.631203 -121.210999 -0.475708 -0.785100 0.396635  
 446 225.082794 66.709602 -121.811996 -0.484203 -0.780528 0.395378  
 447 225.774002 66.769897 -122.416000 -0.492627 -0.775731 0.394411  
 448 226.465195 66.812202 -123.021004 -0.500949 -0.770731 0.393732  
 449 227.156403 66.836403 -123.628998 -0.509191 -0.765510 0.393343  
 450 227.847595 66.842697 -124.238998 -0.517337 -0.760082 0.393241  
 451 228.538803 66.831001 -124.851997 -0.525393 -0.754438 0.393428  
 452 229.229996 66.801201 -125.466003 -0.533329 -0.748598 0.393906  
 453 229.921204 66.753403 -126.083000 -0.541166 -0.742546 0.394672  
 454 230.612396 66.687698 -126.702003 -0.548885 -0.736293 0.395724  
 455 231.303604 66.603897 -127.321999 -0.556469 -0.729849 0.397067  
 456 231.994797 66.502098 -127.945999 -0.563950 -0.723189 0.398696  
 457 232.686005 66.382301 -128.570999 -0.571284 -0.716341 0.400612  
 458 233.377197 66.244400 -129.199005 -0.578491 -0.709287 0.402816  
 459 234.068405 66.088600 -129.828003 -0.585539 -0.702050 0.405302  
 460 234.759598 65.914803 -130.460007 -0.592447 -0.694610 0.408073

## 89 GHZ

Samp#	Rotate	pointing	pointing	unit vector		
	Angle	theta	phi	xhat	yhat	xhat
410	203.262405	63.735401	-114.912003	-0.377765	-0.813313	0.442511
411	203.953598	64.046799	-115.466003	-0.386640	-0.811782	0.437630
412	204.644806	64.340500	-116.023003	-0.395492	-0.809991	0.433015
413	205.335999	64.616600	-116.583000	-0.404318	-0.807944	0.428665
414	206.027206	64.874901	-117.144997	-0.413101	-0.805651	0.424587
415	206.718399	65.115501	-117.709999	-0.421851	-0.803110	0.420781
416	207.409607	65.338501	-118.278000	-0.430564	-0.800325	0.417247
417	208.100800	65.543701	-118.848000	-0.439222	-0.797306	0.413989
418	208.792007	65.731201	-119.419998	-0.447823	-0.794058	0.411007
419	209.483200	65.901001	-119.996002	-0.456390	-0.790567	0.408303
420	210.174393	66.053101	-120.573997	-0.464892	-0.786854	0.405878
421	210.865601	66.187500	-121.153999	-0.473324	-0.782921	0.403732
422	211.556793	66.304199	-121.737999	-0.481711	-0.778754	0.401867
423	212.248001	66.403198	-122.322998	-0.490007	-0.774381	0.400284
424	212.939194	66.484596	-122.912003	-0.498251	-0.769780	0.398981
425	213.630402	66.548203	-123.502998	-0.506408	-0.764968	0.397962
426	214.321594	66.594101	-124.097000	-0.514490	-0.759941	0.397227
427	215.012802	66.622200	-124.693001	-0.522478	-0.754709	0.396776
428	215.703995	66.632698	-125.292000	-0.530382	-0.749265	0.396607
429	216.395203	66.625504	-125.893997	-0.538195	-0.743611	0.396722
430	217.086395	66.600601	-126.498001	-0.545902	-0.737758	0.397120
431	217.777603	66.557999	-127.105003	-0.553509	-0.731698	0.397802
432	218.468796	66.497704	-127.713997	-0.560998	-0.725442	0.398767
433	219.160004	66.419701	-128.326004	-0.568378	-0.718982	0.400014
434	219.851196	66.323997	-128.940994	-0.575642	-0.712319	0.401544
435	220.542404	66.210503	-129.557999	-0.582772	-0.705465	0.403357
436	221.233597	66.079399	-130.177994	-0.589774	-0.698411	0.405449

437 221.924805 65.930603 -130.800995 -0.596644 -0.691157 0.407821  
 438 222.615997 65.764000 -131.425995 -0.603360 -0.683716 0.410473  
 439 223.307205 65.579803 -132.054001 -0.609931 -0.676079 0.413402  
 440 223.998398 65.377899 -132.684006 -0.616337 -0.668257 0.416608

### 166 GHZ

Samp#	Rotate Angle	pointing theta	pointing phi	xhat	yhat	unit vector xhat
392	192.407501	70.125999	-97.226196	-0.118316	-0.932966	0.339965
393	193.098694	70.708900	-97.949600	-0.130556	-0.934775	0.330379
394	193.789902	71.274498	-98.673599	-0.142842	-0.936230	0.321045
395	194.481094	71.822601	-99.398300	-0.155166	-0.937336	0.311970
396	195.172302	72.353401	-100.124001	-0.167526	-0.938101	0.303154
397	195.863495	72.866699	-100.849998	-0.179902	-0.938533	0.294604
398	196.554703	73.362602	-101.577003	-0.192300	-0.938638	0.286321
399	197.245895	73.841202	-102.304001	-0.204697	-0.938427	0.278307
400	197.937103	74.302299	-103.032997	-0.217117	-0.937898	0.270568
401	198.628296	74.746002	-103.762001	-0.229524	-0.937067	0.263104
402	199.319504	75.172302	-104.490997	-0.241911	-0.935941	0.255917
403	200.010696	75.581200	-105.222000	-0.254304	-0.934517	0.249011
404	200.701904	75.972702	-105.953003	-0.266667	-0.932811	0.242387
405	201.393097	76.346703	-106.683998	-0.278994	-0.930829	0.236048
406	202.084305	76.703400	-107.417000	-0.291314	-0.928569	0.229993
407	202.775497	77.042702	-108.150002	-0.303588	-0.926044	0.224225
408	203.466705	77.364502	-108.884003	-0.315828	-0.923256	0.218747
409	204.157898	77.668999	-109.617996	-0.328015	-0.920217	0.213558
410	204.849106	77.956001	-110.353996	-0.340176	-0.916919	0.208661
411	205.540298	78.225601	-111.089996	-0.352275	-0.913380	0.204056
412	206.231506	78.477898	-111.825996	-0.364309	-0.909606	0.199742
413	206.922699	78.712700	-112.564003	-0.376305	-0.905586	0.195724
414	207.613907	78.930099	-113.302002	-0.388229	-0.901340	0.192001
415	208.305099	79.130096	-114.040001	-0.400077	-0.896872	0.188574
416	208.996307	79.312698	-114.779999	-0.411876	-0.892171	0.185442
417	209.687500	79.477898	-115.519997	-0.423593	-0.887256	0.182607
418	210.378693	79.625702	-116.261002	-0.435239	-0.882124	0.180069
419	211.069901	79.756104	-117.001999	-0.446795	-0.876784	0.177829
420	211.761093	79.869003	-117.745003	-0.458289	-0.871226	0.175889
421	212.452301	79.964600	-118.487000	-0.469672	-0.865475	0.174246
422	213.143494	80.042801	-119.231003	-0.480987	-0.859510	0.172901
423	213.834702	80.103500	-119.974998	-0.492198	-0.853350	0.171856
424	214.525894	80.146797	-120.721001	-0.503333	-0.846981	0.171111
425	215.217102	80.172798	-121.466003	-0.514344	-0.840431	0.170663
426	215.908295	80.181297	-122.212997	-0.525270	-0.833676	0.170516
427	216.599503	80.172401	-122.959999	-0.536080	-0.826735	0.170668
428	217.290695	80.146103	-123.708000	-0.546784	-0.819601	0.171120
429	217.981903	80.102402	-124.456001	-0.557363	-0.812285	0.171871
430	218.673096	80.041298	-125.205002	-0.567828	-0.804780	0.172920

431 219.364304 79.962799 -125.955002 -0.578174 -0.797086 0.174269  
 432 220.055496 79.866898 -126.706001 -0.588397 -0.789204 0.175916  
 433 220.746704 79.753601 -127.457001 -0.598477 -0.781147 0.177861  
 434 221.437897 79.622902 -128.209000 -0.608426 -0.772904 0.180105  
 435 222.129105 79.474701 -128.962006 -0.618236 -0.764476 0.182648  
 436 222.820297 79.309196 -129.716003 -0.627903 -0.755866 0.185486  
 437 223.511505 79.126198 -130.470001 -0.637408 -0.747083 0.188623  
 438 224.202698 78.925903 -131.225006 -0.646758 -0.738119 0.192054  
 439 222.592896 79.758797 -122.005997 -0.521575 -0.834479 0.177778  
 440 223.284103 79.737900 -122.761002 -0.532490 -0.827479 0.178136  
 441 223.975296 79.698196 -123.517998 -0.543308 -0.820269 0.178817  
 442 224.666504 79.639801 -124.276001 -0.554009 -0.812859 0.179819

### 183 GHZ

Samp#	Rotate Angle	pointing theta	pointing phi	unit vector xhat	unit vector yhat	unit vector zhat
398	194.253693	64.489403	-92.211899	-0.034858	-0.901825	0.430694
399	194.944901	65.236504	-92.911201	-0.046143	-0.906864	0.418889
400	195.636093	65.964798	-93.611801	-0.057559	-0.911473	0.407313
401	196.327301	66.674400	-94.313797	-0.069095	-0.915660	0.395970
402	197.018494	67.365303	-95.017197	-0.080742	-0.919433	0.384868
403	197.709702	68.037399	-95.722000	-0.092489	-0.922800	0.374014
404	198.400894	68.690804	-96.428101	-0.104324	-0.925769	0.363413
405	199.092102	69.325500	-97.135597	-0.116240	-0.928348	0.353070
406	199.783295	69.941399	-97.844498	-0.128227	-0.930545	0.342992
407	200.474503	70.538597	-98.554703	-0.140275	-0.932369	0.333182
408	201.165695	71.117104	-99.266296	-0.152377	-0.933828	0.323645
409	201.856903	71.676804	-99.979301	-0.164525	-0.934929	0.314386
410	202.548096	72.217796	-100.694000	-0.176717	-0.935680	0.305408
411	203.239304	72.740097	-101.408997	-0.188921	-0.936093	0.296714
412	203.930496	73.243698	-102.126999	-0.201177	-0.936166	0.288308
413	204.621704	73.728500	-102.845001	-0.213426	-0.935917	0.280195
414	205.312897	74.194603	-103.565002	-0.225697	-0.935346	0.272376
415	206.004105	74.641899	-104.286003	-0.237966	-0.934464	0.264855
416	206.695297	75.070503	-105.009003	-0.250244	-0.933275	0.257634
417	207.386505	75.480400	-105.733002	-0.262510	-0.931789	0.250714
418	208.077698	75.871597	-106.458000	-0.274757	-0.930013	0.244098
419	208.768906	76.244003	-107.184998	-0.286998	-0.927949	0.237789
420	209.460098	76.597702	-107.913002	-0.299210	-0.925607	0.231787
421	210.151306	76.932701	-108.641998	-0.311390	-0.922994	0.226095
422	210.842499	77.248901	-109.373001	-0.323549	-0.920109	0.220715
423	211.533707	77.546402	-110.105003	-0.335667	-0.916965	0.215647
424	212.224899	77.825104	-110.838997	-0.347755	-0.913559	0.210894
425	212.916107	78.085197	-111.572998	-0.359777	-0.909911	0.206454
426	213.607300	78.326500	-112.309998	-0.371778	-0.906004	0.202330
427	214.298492	78.549103	-113.046997	-0.383705	-0.901864	0.198523
428	214.989700	78.752899	-113.786003	-0.395588	-0.897481	0.195035

429 215.680893 78.938004 -114.527000 -0.407421 -0.892859 0.191864  
430 216.372101 79.104401 -115.267998 -0.419169 -0.888015 0.189013  
431 217.063293 79.251999 -116.012001 -0.430877 -0.882932 0.186482  
432 217.754501 79.380898 -116.755997 -0.442493 -0.877636 0.184270  
433 218.445694 79.491096 -117.501999 -0.454045 -0.872113 0.182379  
434 219.136902 79.582603 -118.249001 -0.465514 -0.866375 0.180807  
435 219.828094 79.655296 -118.998001 -0.476910 -0.860416 0.179558  
436 220.519302 79.709297 -119.748001 -0.488215 -0.854246 0.178630  
437 221.210495 79.744499 -120.499001 -0.499426 -0.847869 0.178025  
438 221.901703 79.761101 -121.251999 -0.510552 -0.841276 0.177739  
439 222.592896 79.758797 -122.005997 -0.521575 -0.834479 0.177778  
440 223.284103 79.737900 -122.761002 -0.532490 -0.827479 0.178136  
441 223.975296 79.698196 -123.517998 -0.543308 -0.820269 0.178817  
442 224.666504 79.639801 -124.276001 -0.554009 -0.812859 0.179819  
443 225.357697 79.562698 -125.036003 -0.564603 -0.805240 0.181142  
444 226.048904 79.466797 -125.796997 -0.575070 -0.797423 0.182787  
445 226.740097 79.352203 -126.558998 -0.585405 -0.789410 0.184752  
446 227.431305 79.218903 -127.322998 -0.595617 -0.781190 0.187037  
447 228.122498 79.066803 -128.087997 -0.605686 -0.772774 0.189643  
448 228.813705 78.896004 -128.854004 -0.615605 -0.764164 0.192569  
449 229.504898 78.706497 -129.621994 -0.625383 -0.755350 0.195812  
450 230.196106 78.498299 -130.391006 -0.635000 -0.746341 0.199374  
451 230.887299 78.271301 -131.162003 -0.644460 -0.737129 0.203254  
452 231.578506 78.025497 -131.934006 -0.653745 -0.727723 0.207452  
398 194.253693 64.489403 -92.211899 -0.034858 -0.901825 0.430694  
399 194.944901 65.236504 -92.911201 -0.046143 -0.906864 0.418889  
400 195.636093 65.964798 -93.611801 -0.057559 -0.911473 0.407313  
401 196.327301 66.674400 -94.313797 -0.069095 -0.915660 0.395970  
402 197.018494 67.365303 -95.017197 -0.080742 -0.919433 0.384868  
403 197.709702 68.037399 -95.722000 -0.092489 -0.922800 0.374014  
404 198.400894 68.690804 -96.428101 -0.104324 -0.925769 0.363413  
405 199.092102 69.325500 -97.135597 -0.116240 -0.928348 0.353070  
406 199.783295 69.941399 -97.844498 -0.128227 -0.930545 0.342992  
407 200.474503 70.538597 -98.554703 -0.140275 -0.932369 0.333182  
408 201.165695 71.117104 -99.266296 -0.152377 -0.933828 0.323645  
409 201.856903 71.676804 -99.979301 -0.164525 -0.934929 0.314386  
410 202.548096 72.217796 -100.694000 -0.176717 -0.935680 0.305408  
411 203.239304 72.740097 -101.408997 -0.188921 -0.936093 0.296714  
412 203.930496 73.243698 -102.126999 -0.201177 -0.936166 0.288308  
413 204.621704 73.728500 -102.845001 -0.213426 -0.935917 0.280195  
414 205.312897 74.194603 -103.565002 -0.225697 -0.935346 0.272376  
415 206.004105 74.641899 -104.286003 -0.237966 -0.934464 0.264855  
416 206.695297 75.070503 -105.009003 -0.250244 -0.933275 0.257634  
417 207.386505 75.480400 -105.733002 -0.262510 -0.931789 0.250714  
418 208.077698 75.871597 -106.458000 -0.274757 -0.930013 0.244098  
419 208.768906 76.244003 -107.184998 -0.286998 -0.927949 0.237789  
420 209.460098 76.597702 -107.913002 -0.299210 -0.925607 0.231787

421 210.151306 76.932701 -108.641998 -0.311390 -0.922994 0.226095  
422 210.842499 77.248901 -109.373001 -0.323549 -0.920109 0.220715  
423 211.533707 77.546402 -110.105003 -0.335667 -0.916965 0.215647  
424 212.224899 77.825104 -110.838997 -0.347755 -0.913559 0.210894  
425 212.916107 78.085197 -111.572998 -0.359777 -0.909911 0.206454  
426 213.607300 78.326500 -112.309998 -0.371778 -0.906004 0.202330  
427 214.298492 78.549103 -113.046997 -0.383705 -0.901864 0.198523  
428 214.989700 78.752899 -113.786003 -0.395588 -0.897481 0.195035  
429 215.680893 78.938004 -114.527000 -0.407421 -0.892859 0.191864  
430 216.372101 79.104401 -115.267998 -0.419169 -0.888015 0.189013  
431 217.063293 79.251999 -116.012001 -0.430877 -0.882932 0.186482  
432 217.754501 79.380898 -116.755997 -0.442493 -0.877636 0.184270  
433 218.445694 79.491096 -117.501999 -0.454045 -0.872113 0.182379  
434 219.136902 79.582603 -118.249001 -0.465514 -0.866375 0.180807  
435 219.828094 79.655296 -118.998001 -0.476910 -0.860416 0.179558  
436 220.519302 79.709297 -119.748001 -0.488215 -0.854246 0.178630  
437 221.210495 79.744499 -120.499001 -0.499426 -0.847869 0.178025  
438 221.901703 79.761101 -121.251999 -0.510552 -0.841276 0.177739  
439 222.592896 79.758797 -122.005997 -0.521575 -0.834479 0.177778  
440 223.284103 79.737900 -122.761002 -0.532490 -0.827479 0.178136  
441 223.975296 79.698196 -123.517998 -0.543308 -0.820269 0.178817  
442 224.666504 79.639801 -124.276001 -0.554009 -0.812859 0.179819  
443 225.357697 79.562698 -125.036003 -0.564603 -0.805240 0.181142  
444 226.048904 79.466797 -125.796997 -0.575070 -0.797423 0.182787  
445 226.740097 79.352203 -126.558998 -0.585405 -0.789410 0.184752  
413 204.621704 73.728500 -102.845001 -0.213426 -0.935917 0.280195  
414 205.312897 74.194603 -103.565002 -0.225697 -0.935346 0.272376  
415 206.004105 74.641899 -104.286003 -0.237966 -0.934464 0.264855  
416 206.695297 75.070503 -105.009003 -0.250244 -0.933275 0.257634  
417 207.386505 75.480400 -105.733002 -0.262510 -0.931789 0.250714  
418 208.077698 75.871597 -106.458000 -0.274757 -0.930013 0.244098  
419 208.768906 76.244003 -107.184998 -0.286998 -0.927949 0.237789  
420 209.460098 76.597702 -107.913002 -0.299210 -0.925607 0.231787  
421 210.151306 76.932701 -108.641998 -0.311390 -0.922994 0.226095  
422 210.842499 77.248901 -109.373001 -0.323549 -0.920109 0.220715  
423 211.533707 77.546402 -110.105003 -0.335667 -0.916965 0.215647  
424 212.224899 77.825104 -110.838997 -0.347755 -0.913559 0.210894  
425 212.916107 78.085197 -111.572998 -0.359777 -0.909911 0.206454  
426 213.607300 78.326500 -112.309998 -0.371778 -0.906004 0.202330  
427 214.298492 78.549103 -113.046997 -0.383705 -0.901864 0.198523  
428 214.989700 78.752899 -113.786003 -0.395588 -0.897481 0.195035  
429 215.680893 78.938004 -114.527000 -0.407421 -0.892859 0.191864  
430 216.372101 79.104401 -115.267998 -0.419169 -0.888015 0.189013  
431 217.063293 79.251999 -116.012001 -0.430877 -0.882932 0.186482  
432 217.754501 79.380898 -116.755997 -0.442493 -0.877636 0.184270  
433 218.445694 79.491096 -117.501999 -0.454045 -0.872113 0.182379  
434 219.136902 79.582603 -118.249001 -0.465514 -0.866375 0.180807

435 219.828094 79.655296 -118.998001 -0.476910 -0.860416 0.179558  
 436 220.519302 79.709297 -119.748001 -0.488215 -0.854246 0.178630  
 437 221.210495 79.744499 -120.499001 -0.499426 -0.847869 0.178025  
 438 221.901703 79.761101 -121.251999 -0.510552 -0.841276 0.177739  
 439 222.592896 79.758797 -122.005997 -0.521575 -0.834479 0.177778  
 440 223.284103 79.737900 -122.761002 -0.532490 -0.827479 0.178136  
 441 223.975296 79.698196 -123.517998 -0.543308 -0.820269 0.178817  
 442 224.666504 79.639801 -124.276001 -0.554009 -0.812859 0.179819  
 443 225.357697 79.562698 -125.036003 -0.564603 -0.805240 0.181142  
 444 226.048904 79.466797 -125.796997 -0.575070 -0.797423 0.182787  
 445 226.740097 79.352203 -126.558998 -0.585405 -0.789410 0.184752  
 446 227.431305 79.218903 -127.322998 -0.595617 -0.781190 0.187037  
 447 228.122498 79.066803 -128.087997 -0.605686 -0.772774 0.189643  
 448 228.813705 78.896004 -128.854004 -0.615605 -0.764164 0.192569  
 449 229.504898 78.706497 -129.621994 -0.625383 -0.755350 0.195812  
 450 230.196106 78.498299 -130.391006 -0.635000 -0.746341 0.199374  
 451 230.887299 78.271301 -131.162003 -0.644460 -0.737129 0.203254  
 452 231.578506 78.025497 -131.934006 -0.653745 -0.727723 0.207452

## **7. APPENDIX C. DIODE EXCESS TEMPERATURE**

DIODE	DIODE EXCESS TEMPERATURE						
TEMP	10V	10H	18V	18H	23V	36V	36 H
-20	216.7974	189.1753	210.8547	204.4932	169.5805	186.7644	196.9413
-19	217.2523	189.5013	211.5019	205.0137	170.2769	186.9826	197.3097
-18	217.702	189.8234	212.1486	205.5354	170.9708	187.2026	197.6782
-17	218.1466	190.1415	212.7948	206.0583	171.6621	187.4245	198.0467
-16	218.5859	190.4557	213.4405	206.5824	172.3509	187.6481	198.4153
-15	219.0201	190.7659	214.0856	207.1076	173.0371	187.8735	198.7838
-14	219.4491	191.0722	214.7302	207.634	173.7207	188.1007	199.1525
-13	219.8728	191.3745	215.3743	208.1616	174.4018	188.3297	199.5211
-12	220.2914	191.6728	216.0179	208.6903	175.0804	188.5605	199.8898
-11	220.7048	191.9671	216.6609	209.2203	175.7564	188.7931	200.2585
-10	221.1129	192.2575	217.3034	209.7514	176.4298	189.0275	200.6273
-9	221.5159	192.544	217.9454	210.2837	177.1007	189.2637	200.9961
-8	221.9137	192.8265	218.5869	210.8172	177.769	189.5017	201.3649
-7	222.3063	193.105	219.2278	211.3518	178.4348	189.7415	201.7338
-6	222.6937	193.3796	219.8682	211.8876	179.098	189.983	202.1027
-5	222.9991	193.6428	220.5081	212.4247	179.7587	190.2264	202.4716
-4	223.3015	193.9017	221.1474	212.9628	180.4168	190.4716	202.8406
-3	223.6011	194.1564	221.7862	213.5022	181.0723	190.7185	203.2096
-2	223.8977	194.4069	222.4245	214.0428	181.7253	190.9673	203.5786
-1	224.1914	194.6531	223.0623	214.5845	182.3757	191.2179	203.9477
0	224.4822	194.8951	223.6995	215.1274	183.0236	191.4702	204.3168
1	224.7701	195.1328	224.3363	215.6715	183.6689	191.7244	204.686
2	225.0551	195.3663	224.9724	216.2167	184.3117	191.9803	205.0552
3	225.3371	195.5956	225.6081	216.7632	184.9519	192.238	205.4244
4	225.6162	195.8206	226.2432	217.3108	185.5896	192.4976	205.7936

5 225.8924 196.0413 226.8779 217.8596 186.2247 192.7589 206.1629  
 6 226.1656 196.2578 227.5119 218.4095 186.8572 193.0114 206.5373  
 7 226.436 196.4701 228.1455 218.9607 187.4872 193.2656 206.9117  
 8 226.7034 196.6781 228.7785 219.513 188.1147 193.5216 207.2861  
 9 226.9679 196.8819 229.411 220.0665 188.7396 193.7795 207.6606  
 10 227.2295 197.0815 230.043 220.6212 189.3619 194.0391 208.0351  
 11 227.4881 197.2768 230.6744 221.1771 189.9817 194.3005 208.4096  
 12 227.7438 197.4678 231.3054 221.7341 190.5989 194.5638 208.7842  
 13 227.9966 197.6546 231.9358 222.2923 191.2135 194.8288 209.1588  
 14 228.2465 197.8372 232.5656 222.8517 191.8256 195.0956 209.5335  
 15 228.4935 198.0155 233.195 223.4123 192.4352 195.3642 209.9082  
 16 228.7375 198.1896 233.8238 223.9741 193.0422 195.6346 210.2829  
 17 228.9786 198.3594 234.4521 224.537 193.6466 195.9068 210.6577  
 18 229.2168 198.525 235.0799 225.1011 194.2485 196.1808 211.0324  
 19 229.4521 198.6864 235.7071 225.6664 194.8479 196.4566 211.4073  
 20 229.6845 198.8435 236.3338 226.2329 195.4446 196.7342 211.7821  
 21 229.9139 198.9964 236.96 226.8005 196.0388 197.0136 212.157  
 22 230.1404 199.145 237.5857 227.3693 196.6305 197.2947 212.5319  
 23 230.364 199.2893 238.2108 227.9393 197.2196 197.5777 212.9069  
 24 230.5847 199.4295 238.8354 228.5105 197.8062 197.8625 213.2819  
 25 230.8024 199.5654 239.4595 229.0829 198.3902 198.1491 213.6569  
 26 231.0172 199.697 240.083 229.6564 198.9716 198.4374 214.032  
 27 231.2291 199.8244 240.7061 230.2311 199.5505 198.7276 214.4071  
 28 231.4381 199.9476 241.3286 230.807 200.1268 199.0195 214.7823  
 29 231.6442 200.0665 241.9505 231.3841 200.7006 199.3133 215.1574  
 30 231.8473 200.1811 242.572 231.9624 201.2718 199.6088 215.5326  
 31 232.0475 200.2916 243.1929 232.5418 201.8405 199.9062 215.9079  
 32 232.2448 200.3977 243.8133 233.1224 202.4066 200.2053 216.2832  
 33 232.4392 200.4997 244.4332 233.7042 202.9702 200.5062 216.6585  
 34 232.6306 200.5974 245.0525 234.2872 203.5312 200.809 217.0338  
 35 232.8191 200.6908 245.6713 234.8713 204.0896 201.1135 217.4092  
 36 233.0047 200.78 246.2896 235.4566 204.6455 201.4198 217.7846  
 37 233.1874 200.865 246.9074 236.0431 205.1988 201.7279 218.1601  
 38 233.3672 200.9457 247.5246 236.6308 205.7496 202.0379 218.5356  
 39 233.544 201.0222 248.1413 237.2197 206.2978 202.3496 218.9111  
 40 233.7179 201.0944 248.7575 237.8097 206.8435 202.6631 219.2867  
 41 233.8889 201.1624 249.3731 238.4009 207.3866 202.9784 219.6622  
 42 234.057 201.2262 249.9883 238.9933 207.9272 203.2955 220.0379  
 43 234.2221 201.2857 250.6029 239.5869 208.4652 203.6144 220.4135  
 44 234.3844 201.3409 251.2169 240.1816 209.0006 203.9351 220.7892  
 45 234.5437 201.3919 251.8305 240.7776 209.5335 204.2575 221.165

## **8. APPENDIX D. APC ALONG SCAN BIASE**

APC\_ALONG\_SCAN\_BIASE  $\Delta T_{\text{const}}$  in K, 14 (sample #,13 channels ) x 221 (pixel)  
 S# ch1 ch2 ch3 ch4 ch5 ch6 ch7 ch8 ch9 ch10 ch11 ch12 ch13  
 7 -0.0584 -0.0287 0.0465 0.126 0.0614 -0.0086 0.0306 0.0242 0.0661 -0.1135 -0.1164 -0.0781 -0.0998  
 8 -0.0591 -0.0295 0.0445 0.1229 0.0601 -0.0085 0.0304 0.024 0.0655 -0.1125 -0.1154 -0.0774 -0.0989

9 -0.0598 -0.0303 0.0425 0.1199 0.0587 -0.0084 0.0301 0.0238 0.0649 -0.1115 -0.1143 -0.0767 -0.098  
 10 -0.0605 -0.0311 0.0405 0.1169 0.0574 -0.0083 0.0298 0.0235 0.0643 -0.1104 -0.1133 -0.076 -0.0971  
 11 -0.0612 -0.0319 0.0385 0.1138 0.0561 -0.0082 0.0295 0.0233 0.0637 -0.1094 -0.1122 -0.0753 -0.0962  
 12 -0.0619 -0.0327 0.0365 0.1108 0.0548 -0.0082 0.0293 0.0231 0.0631 -0.1084 -0.1112 -0.0746 -0.0953  
 13 -0.0626 -0.0335 0.0345 0.1078 0.0534 -0.0081 0.029 0.0229 0.0625 -0.1073 -0.1101 -0.0739 -0.0944  
 14 -0.0633 -0.0343 0.0325 0.1047 0.0521 -0.008 0.0287 0.0227 0.0619 -0.1063 -0.109 -0.0731 -0.0935  
 15 -0.0639 -0.0351 0.0305 0.1017 0.0508 -0.0079 0.0284 0.0224 0.0613 -0.1053 -0.108 -0.0724 -0.0926  
 16 -0.0646 -0.0359 0.0285 0.0987 0.0495 -0.0079 0.0281 0.0222 0.0607 -0.1043 -0.1069 -0.0717 -0.0917  
 17 -0.0653 -0.0367 0.0265 0.0957 0.0481 -0.0078 0.0279 0.022 0.0601 -0.1032 -0.1059 -0.071 -0.0908  
 18 -0.066 -0.0375 0.0245 0.0926 0.0468 -0.0077 0.0276 0.0218 0.0595 -0.1022 -0.1048 -0.0703 -0.0898  
 19 -0.0667 -0.0383 0.0225 0.0896 0.0455 -0.0076 0.0273 0.0216 0.0589 -0.1012 -0.1037 -0.0696 -0.0889  
 20 -0.0674 -0.0391 0.0205 0.0866 0.0442 -0.0075 0.027 0.0213 0.0583 -0.1001 -0.1027 -0.0689 -0.088  
 21 -0.0681 -0.04 0.0185 0.0835 0.0428 -0.0075 0.0267 0.0211 0.0577 -0.0991 -0.1016 -0.0682 -0.0871  
 22 -0.0688 -0.0408 0.0165 0.0805 0.0415 -0.0074 0.0265 0.0209 0.0571 -0.0981 -0.1006 -0.0675 -0.0862  
 23 -0.0695 -0.0416 0.0145 0.0775 0.0402 -0.0073 0.0262 0.0207 0.0565 -0.097 -0.0995 -0.0668 -0.0853  
 24 -0.0701 -0.0424 0.0125 0.0745 0.0389 -0.0072 0.0259 0.0205 0.0559 -0.096 -0.0985 -0.066 -0.0844  
 25 -0.0708 -0.0432 0.0105 0.0714 0.0376 -0.0072 0.0256 0.0202 0.0553 -0.095 -0.0974 -0.0653 -0.0835  
 26 -0.0715 -0.044 0.0085 0.0684 0.0362 -0.0071 0.0254 0.02 0.0547 -0.0939 -0.0963 -0.0646 -0.0826  
 27 -0.0722 -0.0448 0.0066 0.0654 0.0349 -0.007 0.0251 0.0198 0.0541 -0.0929 -0.0953 -0.0639 -0.0817  
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 156 0.003 -0.0212 -0.0148 -0.0362 -0.0293 0.003 -0.0109 -0.0086 -0.0234 0.0403 0.0413 0.0277 0.0354  
 157 0.0051 -0.0197 -0.0121 -0.0334 -0.0274 0.0031 -0.0111 -0.0088 -0.024 0.0413 0.0423 0.0284 0.0363  
 158 0.0073 -0.0183 -0.0094 -0.0307 -0.0255 0.0032 -0.0114 -0.009 -0.0247 0.0423 0.0434 0.0291 0.0372  
 159 0.0095 -0.0169 -0.0067 -0.0279 -0.0236 0.0033 -0.0117 -0.0092 -0.0253 0.0434 0.0445 0.0298 0.0381  
 160 0.0117 -0.0154 -0.0039 -0.0252 -0.0217 0.0033 -0.012 -0.0095 -0.0259 0.0444 0.0455 0.0305 0.039  
 161 0.0139 -0.014 -0.0012 -0.0224 -0.0198 0.0034 -0.0123 -0.0097 -0.0265 0.0454 0.0466 0.0312 0.0399  
 162 0.0161 -0.0126 0.0015 -0.0197 -0.0179 0.0035 -0.0125 -0.0099 -0.0271 0.0464 0.0476 0.032 0.0408  
 163 0.0183 -0.0111 0.0043 -0.0169 -0.016 0.0036 -0.0128 -0.0101 -0.0277 0.0475 0.0487 0.0327 0.0417  
 164 0.0205 -0.0097 0.007 -0.0141 -0.0141 0.0037 -0.0131 -0.0103 -0.0283 0.0485 0.0498 0.0334 0.0427  
 165 0.0227 -0.0083 0.0097 -0.0114 -0.0122 0.0037 -0.0134 -0.0106 -0.0289 0.0495 0.0508 0.0341 0.0436  
 166 0.0248 -0.0068 0.0124 -0.0086 -0.0103 0.0038 -0.0137 -0.0108 -0.0295 0.0506 0.0519 0.0348 0.0445  
 167 0.027 -0.0054 0.0152 -0.0059 -0.0084 0.0039 -0.0139 -0.011 -0.0301 0.0516 0.0529 0.0355 0.0454  
 168 0.0292 -0.004 0.0179 -0.0031 -0.0065 0.004 -0.0142 -0.0112 -0.0307 0.0526 0.054 0.0362 0.0463  
 169 0.0314 -0.0025 0.0206 -0.0004 -0.0046 0.004 -0.0145 -0.0114 -0.0313 0.0537 0.055 0.0369 0.0472  
 170 0.0336 -0.0011 0.0233 0.0024 -0.0027 0.0041 -0.0148 -0.0117 -0.0319 0.0547 0.0561 0.0376 0.0481  
 171 0.0358 0.0003 0.0261 0.0051 -0.0008 0.0042 -0.015 -0.0119 -0.0325 0.0557 0.0572 0.0383 0.049  
 172 0.038 0.0018 0.0288 0.0079 0.0011 0.0043 -0.0153 -0.0121 -0.0331 0.0568 0.0582 0.0391 0.0499  
 173 0.0402 0.0032 0.0315 0.0107 0.003 0.0044 -0.0156 -0.0123 -0.0337 0.0578 0.0593 0.0398 0.0508  
 174 0.0424 0.0046 0.0343 0.0134 0.0049 0.0044 -0.0159 -0.0125 -0.0343 0.0588 0.0603 0.0405 0.0517  
 175 0.0445 0.0061 0.037 0.0162 0.0068 0.0045 -0.0162 -0.0128 -0.0349 0.0599 0.0614 0.0412 0.0526  
 176 0.0467 0.0075 0.0397 0.0189 0.0087 0.0046 -0.0164 -0.013 -0.0355 0.0609 0.0625 0.0419 0.0535  
 177 0.0489 0.0089 0.0424 0.0217 0.0106 0.0047 -0.0167 -0.0132 -0.0361 0.0619 0.0635 0.0426 0.0545  
 178 0.0557 0.0162 0.0452 0.0244 0.0125 0.0047 -0.017 -0.0134 -0.0367 0.063 0.0646 0.0433 0.0554  
 179 0.0626 0.0235 0.0479 0.0272 0.0144 0.0048 -0.0173 -0.0136 -0.0373 0.064 0.0656 0.044 0.0563

180 0.0694 0.0307 0.0506 0.0299 0.0163 0.0049 -0.0176 -0.0139 -0.0379 0.065 0.0667 0.0447 0.0572  
 181 0.0762 0.038 0.0533 0.0327 0.0182 0.005 -0.0178 -0.0141 -0.0385 0.0661 0.0678 0.0454 0.0581  
 182 0.083 0.0453 0.0561 0.0354 0.0201 0.0051 -0.0181 -0.0143 -0.0391 0.0671 0.0688 0.0462 0.059  
 183 0.0898 0.0525 0.0588 0.0382 0.022 0.0051 -0.0184 -0.0145 -0.0397 0.0681 0.0699 0.0469 0.0599  
 184 0.0966 0.0598 0.0615 0.041 0.0239 0.0052 -0.0187 -0.0147 -0.0403 0.0692 0.0709 0.0476 0.0608  
 185 0.1035 0.0671 0.0643 0.0437 0.0258 0.0053 -0.0189 -0.015 -0.0409 0.0702 0.072 0.0483 0.0617  
 186 0.1103 0.0744 0.067 0.0465 0.0278 0.0054 -0.0192 -0.0152 -0.0415 0.0712 0.073 0.049 0.0626  
 187 0.1171 0.0816 0.0697 0.0492 0.0297 0.0054 -0.0195 -0.0154 -0.0421 0.0723 0.0741 0.0497 0.0635  
 188 0.1239 0.0889 0.0724 0.052 0.0316 0.0055 -0.0198 -0.0156 -0.0427 0.0733 0.0752 0.0504 0.0644  
 189 0.1307 0.0962 0.0752 0.0547 0.0335 0.0056 -0.0201 -0.0158 -0.0433 0.0743 0.0762 0.0511 0.0653  
 190 0.1375 0.1034 0.0779 0.0575 0.0354 0.0057 -0.0203 -0.0161 -0.0439 0.0754 0.0773 0.0518 0.0663  
 191 0.1444 0.1107 0.0806 0.0602 0.0373 0.0058 -0.0206 -0.0163 -0.0445 0.0764 0.0783 0.0525 0.0672  
 192 0.1512 0.118 0.0833 0.063 0.0392 0.0058 -0.0209 -0.0165 -0.0451 0.0774 0.0794 0.0533 0.0681  
 193 0.158 0.1253 0.0861 0.0658 0.0411 0.0059 -0.0212 -0.0167 -0.0457 0.0784 0.0805 0.054 0.069  
 194 0.1648 0.1325 0.0888 0.0685 0.043 0.006 -0.0215 -0.0169 -0.0463 0.0795 0.0815 0.0547 0.0699  
 195 0.1716 0.1398 0.0915 0.0713 0.0449 0.0061 -0.0217 -0.0172 -0.0469 0.0805 0.0826 0.0554 0.0708  
 196 0.1784 0.1471 0.0943 0.074 0.0468 0.0061 -0.022 -0.0174 -0.0475 0.0815 0.0836 0.0561 0.0717  
 197 0.1853 0.1543 0.097 0.0768 0.0487 0.0062 -0.0223 -0.0176 -0.0481 0.0826 0.0847 0.0568 0.0726  
 198 0.1921 0.1616 0.0997 0.0795 0.0506 0.0063 -0.0226 -0.0178 -0.0487 0.0836 0.0857 0.0575 0.0735  
 199 0.1989 0.1689 0.1024 0.0823 0.0525 0.0064 -0.0228 -0.018 -0.0493 0.0846 0.0868 0.0582 0.0744  
 200 0.2057 0.1762 0.1052 0.085 0.0544 0.0065 -0.0231 -0.0183 -0.0499 0.0857 0.0879 0.0589 0.0753  
 201 0.2125 0.1834 0.1079 0.0878 0.0563 0.0065 -0.0234 -0.0185 -0.0505 0.0867 0.0889 0.0597 0.0762  
 202 0.2193 0.1907 0.1106 0.0906 0.0582 0.0066 -0.0237 -0.0187 -0.0511 0.0877 0.09 0.0604 0.0771  
 203 0.2262 0.198 0.1238 0.1029 0.0601 0.0067 -0.024 -0.0189 -0.0517 0.0888 0.091 0.0611 0.0781  
 204 0.233 0.2052 0.137 0.1152 0.062 0.0068 -0.0242 -0.0191 -0.0523 0.0898 0.0921 0.0618 0.079  
 205 0.2398 0.2125 0.1502 0.1275 0.0675 0.0068 -0.0245 -0.0194 -0.0529 0.0908 0.0932 0.0625 0.0799  
 206 0.2466 0.2198 0.1634 0.1399 0.073 0.0069 -0.0248 -0.0196 -0.0535 0.0919 0.0942 0.0632 0.0808  
 207 0.2534 0.2271 0.1766 0.1522 0.0785 0.007 -0.0251 -0.0198 -0.0541 0.0929 0.0953 0.0639 0.0817  
 208 0.2602 0.2343 0.1898 0.1645 0.084 0.0071 -0.0254 -0.02 -0.0547 0.0939 0.0963 0.0646 0.0826  
 209 0.2671 0.2416 0.203 0.1768 0.0895 0.0072 -0.0256 -0.0202 -0.0553 0.095 0.0974 0.0653 0.0835  
 210 0.2739 0.2489 0.2161 0.1892 0.095 0.0072 -0.0259 -0.0205 -0.0559 0.096 0.0985 0.066 0.0844  
 211 0.2807 0.2561 0.2293 0.2015 0.1005 0.0073 -0.0262 -0.0207 -0.0565 0.097 0.0995 0.0668 0.0853  
 212 0.2875 0.2634 0.2425 0.2138 0.106 0.0074 -0.0265 -0.0209 -0.0571 0.0981 0.1006 0.0675 0.0862  
 213 0.2943 0.2707 0.2557 0.2262 0.1115 0.0075 -0.0267 -0.0211 -0.0577 0.0991 0.1016 0.0682 0.0871  
 214 0.3011 0.2779 0.2689 0.2385 0.117 0.0075 -0.027 -0.0213 -0.0583 0.1001 0.1027 0.0689 0.088  
 215 0.3079 0.2852 0.2821 0.2508 0.1225 0.0076 -0.0273 -0.0216 -0.0589 0.1012 0.1037 0.0696 0.0889  
 216 0.3148 0.2925 0.2953 0.2631 0.128 0.0077 -0.0276 -0.0218 -0.0595 0.1022 0.1048 0.0703 0.0898  
 217 0.3216 0.2998 0.3085 0.2755 0.1335 0.0078 -0.0279 -0.022 -0.0601 0.1032 0.1059 0.071 0.0908  
 218 0.3284 0.307 0.3217 0.2878 0.139 0.0079 -0.0281 -0.0222 -0.0607 0.1043 0.1069 0.0717 0.0917  
 219 0.3352 0.3143 0.3349 0.3001 0.1445 0.0079 -0.0284 -0.0224 -0.0613 0.1053 0.108 0.0724 0.0926  
 220 0.342 0.3216 0.3481 0.3125 0.15 0.008 -0.0287 -0.0227 -0.0619 0.1063 0.109 0.0731 0.0935  
 221 0.3488 0.3288 0.3612 0.3248 0.1555 0.0081 -0.029 -0.0229 -0.0625 0.1073 0.1101 0.0739 0.0944  
 222 0.3557 0.3361 0.3744 0.3371 0.161 0.0082 -0.0293 -0.0231 -0.0631 0.1084 0.1112 0.0746 0.0953  
 223 0.3625 0.3434 0.3876 0.3494 0.1665 0.0082 -0.0295 -0.0233 -0.0637 0.1094 0.1122 0.0753 0.0962  
 224 0.3693 0.3507 0.4008 0.3618 0.172 0.0083 -0.0298 -0.0235 -0.0643 0.1104 0.1133 0.076 0.0971  
 225 0.3761 0.3579 0.414 0.3741 0.1775 0.0084 -0.0301 -0.0238 -0.0649 0.1115 0.1143 0.0767 0.098  
 226 0.3829 0.3652 0.4272 0.3864 0.183 0.0085 -0.0304 -0.024 -0.0655 0.1125 0.1154 0.0774 0.0989  
 227 0.3897 0.3725 0.4404 0.3987 0.1885 0.0086 -0.0306 -0.0242 -0.0661 0.1135 0.1164 0.0781 0.09

## **9. APPENDIX E. APC ALONG SCAN MULTIPLICATIVE BIAS TERM**

$\Delta t_{\text{multi}}$  in K/K 14 (sample number, 13 channels) x 221 (pixels)

S#	ch1	ch2	ch3	ch4	ch5	ch6	ch7	ch8	ch9	ch10	ch11	ch12	ch13
7	7.07E-04	1.60E-03	5.94E-04	9.56E-04	2.71E-04	3.23E-03	4.80E-03	0	0	0	0	0	0
8	6.82E-04	1.54E-03	5.07E-04	9.10E-04	1.94E-04	2.76E-03	4.10E-03	0	0	0	0	0	0

9 6.58E-04 1.49E-03 4.23E-04 8.65E-04 1.36E-04 2.34E-03 3.48E-03 0 0 0 0 0  
10 6.33E-04 1.43E-03 3.42E-04 8.19E-04 9.47E-05 1.98E-03 2.93E-03 0 0 0 0 0  
11 6.09E-04 1.38E-03 2.66E-04 7.74E-04 6.65E-05 1.66E-03 2.46E-03 0 0 0 0 0  
12 5.85E-04 1.32E-03 1.96E-04 7.28E-04 4.78E-05 1.38E-03 2.04E-03 0 0 0 0 0  
13 5.60E-04 1.27E-03 1.35E-04 6.83E-04 3.53E-05 1.14E-03 1.69E-03 0 0 0 0 0  
14 5.36E-04 1.21E-03 8.31E-05 6.37E-04 2.54E-05 9.36E-04 1.38E-03 0 0 0 0 0  
15 5.12E-04 1.16E-03 4.22E-05 5.92E-04 1.48E-05 7.65E-04 1.12E-03 0 0 0 0 0  
16 4.87E-04 1.10E-03 1.37E-05 5.46E-04 0 6.23E-04 9.11E-04 0 0 0 0 0  
17 4.63E-04 1.05E-03 -8.33E-07 5.01E-04 0 5.06E-04 7.34E-04 0 0 0 0 0  
18 4.39E-04 9.91E-04 0 4.55E-04 0 4.11E-04 5.91E-04 0 0 0 0 0  
19 4.14E-04 9.36E-04 0 4.10E-04 0 3.34E-04 4.74E-04 0 0 0 0 0  
20 3.90E-04 8.81E-04 0 3.64E-04 0 2.71E-04 3.80E-04 0 0 0 0 0  
21 3.65E-04 8.26E-04 0 3.19E-04 0 2.19E-04 3.03E-04 0 0 0 0 0  
22 3.41E-04 7.71E-04 0 2.73E-04 0 1.75E-04 2.39E-04 0 0 0 0 0  
23 3.17E-04 7.16E-04 0 2.28E-04 0 1.34E-04 1.81E-04 0 0 0 0 0  
24 2.92E-04 6.61E-04 0 1.82E-04 0 9.40E-05 1.25E-04 0 0 0 0 0  
25 2.68E-04 6.06E-04 0 1.37E-04 0 5.04E-05 6.68E-05 0 0 0 0 0  
26 2.44E-04 5.51E-04 0 9.10E-05 0 0 0 0 0 0 0 0 0  
27 2.19E-04 4.96E-04 0 4.55E-05 0 0 0 0 0 0 0 0 0  
28 1.95E-04 4.41E-04 0 0 0 0 0 0 0 0 0 0 0 0  
29 1.71E-04 3.86E-04 0 0 0 0 0 0 0 0 0 0 0 0  
30 1.46E-04 3.30E-04 0 0 0 0 0 0 0 0 0 0 0 0  
31 1.22E-04 2.75E-04 0 0 0 0 0 0 0 0 0 0 0 0  
32 9.74E-05 2.20E-04 0 0 0 0 0 0 0 0 0 0 0 0  
33 7.31E-05 1.65E-04 0 0 0 0 0 0 0 0 0 0 0 0  
34 4.87E-05 1.10E-04 0 0 0 0 0 0 0 0 0 0 0 0  
35 2.44E-05 5.51E-05 0 0 0 0 0 0 0 0 0 0 0 0  
36 0 0 0 0 0 0 0 0 0 0 0 0 0 0  
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184 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0  
185 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0  
186 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0  
187 1.64E-06 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0  
188 3.24E-05 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0  
189 7.87E-05 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0  
190 1.31E-04 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0  
191 1.84E-04 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0  
192 2.34E-04 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0  
193 2.79E-04 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0  
194 3.21E-04 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0  
195 3.62E-04 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0  
196 4.04E-04 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0  
197 4.51E-04 7.22E-05 0 0 0 0 0 0 0 0 0 0 0 0 0 0  
198 5.06E-04 9.84E-05 0 0 0 0 0 0 0 0 0 0 0 0 0 0  
199 5.72E-04 1.07E-04 0 0 0 0 0 0 0 0 0 0 0 0 0 0  
200 6.53E-04 1.14E-04 0 0 0 0 0 0 0 0 0 0 0 0 0 0  
201 7.51E-04 1.26E-04 0 0 0 0 0 0 0 0 0 0 0 0 0 0  
202 8.67E-04 1.46E-04 0 0 0 0 0 0 0 0 0 0 0 0 0 0  
203 1.00E-03 1.75E-04 0 0 0 0 0 0 0 0 0 0 0 0 0 0  
204 1.16E-03 2.13E-04 0 0 0 0 0 0 0 0 0 0 0 0 0 0  
205 1.34E-03 2.60E-04 0 0 0 0 0 0 0 0 0 0 0 0 0 0  
206 1.54E-03 3.17E-04 0 0 0 0 0 0 0 0 0 0 0 0 0 0  
207 1.75E-03 3.86E-04 0 0 0 0 0 0 0 0 0 0 0 0 0 0  
208 1.99E-03 4.67E-04 0 0 0 0 0 0 0 0 0 0 0 0 0 0  
209 2.23E-03 5.63E-04 0 0 0 0 0 0 0 0 0 0 0 0 0 0  
210 2.50E-03 6.74E-04 0 0 0 0 0 0 0 0 0 0 0 0 0 0  
211 2.77E-03 8.01E-04 0 0 0 0 0 0 0 0 0 0 0 0 0 0  
212 3.06E-03 9.45E-04 0 0 0 0 0 0 0 0 0 0 0 0 0 0  
213 3.37E-03 1.11E-03 0 0 0 0 0 0 0 0 0 0 0 0 0 0  
214 3.69E-03 1.29E-03 0 0 0 0 0 0 0 0 0 0 0 0 0 0  
215 4.04E-03 1.49E-03 0 0 0 0 0 0 0 0 0 0 0 0 0 0  
216 4.42E-03 1.71E-03 0 0 0 0 0 0 0 0 0 0 0 0 0 0  
217 4.84E-03 1.97E-03 0 0 0 0 0 0 0 0 0 0 0 0 0 0  
218 5.32E-03 2.27E-03 0 0 0 0 0 0 0 0 0 0 0 0 0 0  
219 5.89E-03 2.64E-03 5.44E-05 0 1.25E-06 0 0 0 0 0 0 0 0  
220 6.56E-03 3.08E-03 1.20E-04 0 1.49E-05 0 0 0 0 0 0 0 0  
221 7.37E-03 3.63E-03 1.97E-04 0 4.08E-05 0 0 0 0 0 0 0 0  
222 8.36E-03 4.31E-03 2.85E-04 0 7.92E-05 0 0 0 0 0 0 0 0  
223 9.58E-03 5.14E-03 3.84E-04 0 1.30E-04 0 0 0 0 0 0 0 0  
224 1.11E-02 6.16E-03 4.94E-04 8.58E-05 1.93E-04 0 0 0 0 0 0 0 0  
225 1.29E-02 7.37E-03 6.16E-04 1.94E-04 2.68E-04 0 0 0 0 0 0 0 0  
226 1.52E-02 8.77E-03 7.48E-04 3.24E-04 3.56E-04 0 0 0 0 0 0 0 0  
227 1.81E-02 1.03E-02 8.92E-04 4.76E-04 4.56E-04 0 0 0 0 0 0 0 0

## **10. APPENDIX F. ALONG SCAN CORRECTION DUE TO MAGNETICS OF GMI**

1B\_TAM\_GAMMA  $\gamma$  14 (sample # and 13 channel) x 465 (sample) in counts  
 1 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0  
 2 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0  
 3 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0

4 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0  
 5 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0  
 6 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0  
 7 -1.5427 0.693 -0.7793 -0.2168 1.0172 2.5582 0.3591 -0.36 -0.8298 1.4666 0.7478 -0.8739 -3.3214  
 8 1.1761 -1.0654 -0.784 -0.619 0.1167 2.8052 0.0962 -0.0183 -0.9616 1.2781 0.7195 -1.4878 -3.3936  
 9 2.1259 -1.2476 0.0167 -0.6946 -0.4803 1.8569 -0.2254 1.0035 -0.3964 0.9846 0.6181 -1.3241 -2.4085  
 10 -0.0197 0.3954 0.9972 -0.1176 -0.0149 1.5874 0.1698 1.9573 0.3679 0.9029 0.702 -0.2914 -1.5232  
 11 -1.8841 1.1246 1.3532 0.6928 1.1614 2.3689 0.9569 1.2111 -0.0631 0.8921 0.5651 1.0619 -0.8884  
 12 -1.7787 0.4004 0.5935 0.6181 1.6215 3.7654 1.2431 -0.929 -1.5899 0.9874 0.5028 0.4508 -0.7557  
 13 0.2561 -1.2375 0.3722 0.2642 1.0486 4.3396 1.3778 -1.3691 -2.1208 0.9425 0.3305 -0.7994 -1.5779  
 14 1.929 -2.1708 1.0919 -0.0428 0.0974 3.232 0.8588 -0.1771 -1.6226 0.8277 0.1958 -1.4092 -1.2423  
 15 0.8681 -0.8639 2.0378 0.07 -0.022 2.0853 1.207 1.7289 0.0705 0.6078 0.1726 -1.0586 -0.5538  
 16 -1.7608 0.8156 2.2715 0.323 0.6513 1.6185 1.4586 1.7649 0.3692 0.7756 0.2607 0.0695 -1.0716  
 17 -3.023 1.1248 1.7486 0.6695 1.4827 1.9729 1.7147 0.1009 -0.3948 0.6624 0.0544 -0.6297 -2.5945  
 18 -1.5519 -0.6003 0.693 0.1776 1.4118 2.2119 1.4374 -0.9169 -1.2252 0.5496 0.0701 -1.9681 -3.8149  
 19 1.2456 -2.3263 1.2466 -0.3605 0.1958 1.1678 0.7632 -0.0648 -0.7279 0.4021 -0.1717 -2.7575 -4.0787  
 20 1.4299 -1.9782 1.6217 -0.6651 -0.5691 -0.0941 0.2193 1.2294 0.2673 0.1494 -0.1545 -2.9065 -3.7382  
 21 -0.7981 -0.4274 1.8181 -0.2704 -0.3624 0.1077 0.9717 2.1496 1.2623 0.1085 -0.0998 -2.1866 -4.0004  
 22 -2.5439 -0.0395 1.1655 -0.0151 0.3301 0.9905 1.382 1.5399 1.1948 0.2791 0.0295 -1.1919 -3.4068  
 23 -1.6368 -1.5199 -0.1575 -0.0389 0.5714 2.2722 1.6578 -0.0558 0.1643 0.3094 -0.025 -2.0703 -4.1203  
 24 1.1191 -3.8728 -0.7203 -0.4351 -0.2283 2.5155 1.3678 0.0145 0.0301 0.4458 0.1425 -3.0395 -4.9839  
 25 2.8698 -4.857 -0.3889 -0.6445 -1.2015 1.0534 0.7195 0.8669 0.4268 0.2306 0.2739 -3.4141 -4.891  
 26 1.565 -3.9332 0.2108 -0.434 -1.2726 0.1063 0.6304 1.5154 0.6906 -0.0547 0.2214 -2.9655 -4.5962  
 27 -0.4638 -2.9687 0.185 0.0565 -0.5456 0.2628 1.0384 1.1439 0.423 0.1533 0.3172 -1.1911 -3.496  
 28 -1.1663 -3.5406 -0.6006 0.6407 0.2855 1.6516 1.1624 -0.9616 -1.1063 0.1857 0.0816 -0.8786 -2.4956  
 29 0.6232 -5.6075 -1.2965 0.2232 0.0755 3.1175 1.2864 -1.945 -2.2706 0.3944 0.1049 -1.8452 -2.7521  
 30 2.7741 -7.2187 -0.9195 -2.3373 -0.7592 2.3507 0.7358 -0.8883 -1.7751 0.4275 0.1658 -2.2628 -2.354  
 31 2.593 -6.7559 -0.0059 -0.0976 -1.1081 0.9296 0.5047 0.3383 -0.815 0.0738 0.006 -2.2686 -1.7037  
 32 0.2005 -5.298 0.5503 0.0456 -0.6242 0.5097 0.948 0.9871 0.0121 0.2485 -0.0793 -1.2229 -1.6061  
 33 -1.5894 -5.169 0.2574 0.2359 0.1372 0.7059 1.0363 0.0379 -0.1569 0.353 -0.0902 -0.3595 -1.1055  
 34 -0.5658 -6.8254 -0.9294 -0.086 0.4474 1.2104 0.663 -1.1833 -1.123 0.4931 -0.1374 -1.7349 -2.918  
 35 1.6634 -9.0637 -0.9538 -0.6869 -0.2834 0.4446 -0.0653 -0.7044 -0.9604 0.3168 -0.2208 -2.8814 -  
 4.4282  
 36 2.6057 -10.0995 -0.1734 -0.9145 -1.1531 -0.9755 -0.6871 0.4206 -0.3 0.2463 -0.0821 -3.1134 -4.2779  
 37 0.8797 -9.4631 0.6518 -0.6756 -0.9125 -1.3944 -0.315 1.2396 0.6258 0.2113 0.2048 -2.2939 -3.624  
 38 -1.4499 -9.2425 0.6726 -0.2963 -0.1862 -0.4657 0.341 0.8346 0.6218 0.3175 0.2709 -0.3771 -2.6174  
 39 -1.7699 -10.8489 -0.111 -0.103 0.4013 1.4643 0.784 -0.8963 -0.3451 0.5999 0.4484 -0.4251 -2.2139  
 40 0.4019 -13.7428 -0.5369 -0.3285 -0.0523 2.8555 1.014 -1.0631 -0.6483 0.5658 0.5158 -1.3409 -  
 2.9165  
 41 2.332 -15.8906 0.1102 -0.6933 -1.0612 2.3218 0.5694 0.0281 -0.0553 0.5671 0.6207 -1.4795 -1.858  
 42 1.6485 -15.6738 0.6233 -0.4983 -1.0292 1.9424 0.7637 0.8474 0.4712 0.4631 0.8369 -1.2978 -1.4027  
 43 -1.0857 -14.711 1.0919 -0.0232 -0.2686 2.3716 1.384 0.8507 0.4662 0.5705 0.8323 0.0268 -0.645  
 44 -2.3733 -15.2017 0.8007 0.4059 0.3531 2.7241 1.6138 -0.4379 -0.2029 0.8189 0.9391 1.0319 0.8676  
 45 -1.4103 -16.9798 0.1074 0.323 0.4196 2.9997 1.2044 -1.5224 -1.0714 0.8212 1.0095 -0.1106 -0.4865  
 46 0.6777 -18.4684 0.2188 0.0076 -0.2775 1.9665 0.2626 -1.2129 -1.1766 0.6828 0.8223 -1.2528 -1.6892  
 47 0.7953 -18.0489 1.0902 -0.0276 -0.9052 0.356 -0.1824 -0.0194 -0.5515 0.6503 0.7832 -1.5264 -  
 1.1812  
 48 -1.5399 -15.8459 1.7383 0.4503 -0.4574 -0.1763 0.1182 0.6643 0.1397 0.8995 1.1137 -0.6114 -0.1699  
 49 -3.715 -14.4739 1.5819 0.8357 0.2332 0.4851 0.5251 0.192 0.1004 1.2545 1.3342 0.8065 0.9928  
 50 -3.8406 -14.3063 0.5316 0.942 0.9237 1.7241 0.6125 -1.1643 -0.6696 1.2577 1.3337 0.1226 0.4456  
 51 -1.5548 -15.2602 0.152 0.7227 0.6078 2.0008 0.5933 -0.8205 -0.3773 1.3314 1.3708 -1.3837 -1.912

52 0.2881 -15.3021 0.6664 0.2245 -0.4022 -0.6868 -0.7394 0.4074 0.3795 0.9829 1.0763 -2.0671 -2.6093  
 53 -0.6032 -13.0209 1.0022 0.1462 -0.406 -2.2192 -1.2202 1.3974 1.3021 0.5641 0.7824 -1.6078 -2.5015  
 54 -2.6611 -10.3673 0.757 0.2083 0.2146 -1.6339 -0.8491 1.1294 0.963 0.8142 0.9318 0.2227 -1.3874  
 55 -3.4735 -9.084 -0.1139 0.4109 0.8698 -0.0475 -0.691 -0.0906 0.1256 0.8532 0.8604 1.1395 0.0288  
 56 -1.7139 -9.1298 -0.94 0.2878 1.0738 1.5391 -0.2845 -0.8684 -0.5128 0.6459 0.7526 0.32 -1.0696  
 57 0.8892 -8.8445 -0.5591 0.1654 0.3061 1.3934 -0.446 -0.0482 -0.1886 0.6499 0.7929 -0.408 -1.5139  
 58 0.959 -6.6927 0.4924 0.3232 -0.2536 0.7473 -0.1106 0.84 0.6334 0.6539 1.1659 0.0067 0.1044  
 59 -0.6604 -3.2554 0.8735 0.6215 0.1929 1.141 0.7572 1.2184 1.2228 0.5525 0.949 1.2442 1.3205  
 60 -2.2806 -0.6491 0.6288 0.9204 0.8821 1.8812 1.2344 0.6448 1.1479 0.9086 1.0278 2.9389 3.0901  
 61 -1.8112 0.3793 -0.2415 0.8471 1.1895 2.7757 1.1791 -0.5748 0.2429 0.9129 1.0703 2.2573 2.1438  
 62 0.5067 0.6597 -0.3071 0.4949 0.5599 1.8223 0.5557 -0.5023 0.1012 0.8115 1.1132 0.6618 0.0408  
 63 1.7383 2.4331 0.566 0.3297 -0.2434 -0.44 -0.0323 0.7263 1.2209 0.7102 1.009 0.0262 -0.1506  
 64 0.2757 5.9485 1.2604 0.4913 -0.2834 -1.778 -0.0169 1.377 2.0084 0.5032 0.9791 0.3048 -0.5934  
 65 -2.032 9.297 1.2397 0.7003 0.3704 -1.9224 0.034 1.1437 1.7333 0.5779 0.8021 2.2743 1.1269  
 66 -2.2501 10.528 0.7274 0.537 0.4689 -1.3737 -0.2347 -0.1774 0.7608 0.3006 0.5149 2.7358 2.3443  
 67 -0.3786 10.762 -0.0531 0.0483 0.1508 -0.5938 -0.397 -0.4786 0.3856 0.1992 0.1174 1.3237 0.0409  
 68 1.7733 11.3271 0.284 -0.1136 -0.4451 -0.5453 -0.5948 0.4104 0.9731 0.0274 0.0156 0.2316 -0.854  
 69 1.7536 13.3022 0.934 -0.0884 -0.7288 -1.4591 -0.4377 1.2654 1.7927 0.2075 0.2833 0.2364 0.3135  
 70 -0.0358 15.7743 1.1371 0.1704 -0.3187 -0.9482 0.1453 1.7125 2.4461 0.0708 0.1086 1.7493 1.6319  
 71 -1.0221 16.876 0.5357 0.4765 0.3341 0.4483 0.5507 0.2556 1.5721 0.0748 0.1927 3.2165 3.4534  
 72 0.1213 16.3997 -0.3786 0.3639 0.6398 1.6524 0.6365 -0.6572 0.7975 -0.062 -0.1657 2.216 2.1061  
 73 2.3894 15.4659 -0.5777 -0.0276 0.0084 0.8932 -0.1652 -0.6179 0.1222 -0.2694 -0.1914 1.1698 0.7588  
 74 3.3701 15.4857 0.2961 -0.6514 -1.109 -0.8669 -1.0735 0.1015 0.3431 -0.2656 -0.2537 0.7176 1.4738  
 75 1.7369 17.4135 0.6782 -0.4358 -0.8038 -1.1254 -0.8104 0.617 0.9291 -0.438 -0.2787 1.7279 2.9433  
 76 -0.5806 19.0083 0.6581 0.1068 -0.0824 1.4268 0.4466 0.1805 0.4855 -0.2233 -0.0818 3.6064 5.2176  
 77 -1.0902 18.7762 0.1016 0.184 0.1182 2.9011 0.816 -0.9019 0.0418 -0.4311 -0.5119 3.5656 5.6308  
 78 0.6506 17.4226 0.0368 0.029 -0.3405 2.6816 0.6884 -1.1003 -0.2029 -0.4631 -0.7202 2.1536 3.3277  
 79 2.2295 16.5246 0.6873 -0.3584 -1.3894 0.3062 -0.3979 -0.3126 0.1829 -0.3896 -0.7066 0.9244 2.2821  
 80 1.315 17.5347 1.3824 -0.4655 -1.7445 -1.5301 -0.6677 0.4072 0.9669 -0.4571 -0.5083 1.0661 3.1478  
 81 -0.9673 18.8343 1.4965 -0.0126 -1.1629 -1.6338 -0.1921 0.4131 1.4187 -0.3488 -0.5309 2.7159  
 4.1643  
 82 -2.3259 18.6804 1.0295 0.1613 -0.512 -1.0828 -0.3556 -0.6689 0.7415 -0.2407 -0.3318 3.7714 5.5328  
 83 -1.5148 17.1561 0.2049 0.103 -0.486 -0.2622 -0.4126 -1.4109 -0.0688 -0.4144 -0.6858 2.8618 3.8329  
 84 0.7827 15.4234 0.1849 -0.1877 -1.1888 -1.251 -1.1443 -1.1328 -0.2153 -0.729 -1.0764 1.8149 2.2837  
 85 1.4711 15.0593 0.9248 -0.2446 -1.6837 -2.2782 -1.2015 -0.3786 0.468 -1.1143 -1.4298 1.362 3.4003  
 86 -0.1329 15.8147 1.3072 -0.0212 -1.3806 -1.3418 -0.3004 0.2396 0.8523 -1.0423 -1.4138 3.0569  
 5.5227  
 87 -1.7781 15.8222 0.9296 0.2028 -0.6961 0.7112 0.2812 -0.264 0.4064 -1.0057 -1.1392 4.9344 7.6449  
 88 -1.535 14.3347 -0.0738 0.2879 -0.1159 2.6104 0.5077 -1.4816 -0.6706 -0.9693 -1.1226 4.2068 7.6544  
 89 0.8778 11.9334 -0.4068 0.0008 -0.3686 2.8156 0.2016 -1.5092 -1.2165 -1.074 -1.1795 2.2451 4.4444  
 90 2.4454 10.8176 0.2884 0.1804 -0.7257 1.327 -0.1756 -0.8226 -0.8995 -1.0382 -1.0147 1.1059 3.3971  
 91 1.1576 11.444 0.9836 0.454 -0.9442 0.108 0.0151 0.034 0.2805 -1.2842 -1.1448 1.2917 4.4118  
 92 -1.1362 12.4014 1.0529 0.6351 -0.5036 -0.1485 -0.0428 0.0407 0.4642 -1.249 -0.9794 3.1683 5.9796  
 93 -2.3457 12.0714 0.3176 0.6771 -0.0632 0.6732 -0.3137 -1.2785 -0.5474 -0.9677 -0.7031 3.8107  
 6.7423  
 94 -1.3855 10.4956 -0.373 0.3004 -0.1783 0.5325 -0.9043 -1.4076 -1.0281 -0.8626 -0.6479 2.3507  
 4.1849  
 95 0.3776 9.1678 -0.0803 -0.1222 -1.0569 -1.6487 -2.276 -0.8227 -0.9778 -0.9339 -0.5924 1.0732 2.3817  
 96 0.2903 9.4577 0.7935 0.0152 -1.5541 -3.0982 -1.9082 -0.3737 -0.3633 -0.8296 -0.4629 0.2982 2.5902  
 97 -1.2051 10.3691 1.2203 0.2931 -1.2534 -2.6997 -1.008 0.0754 0.251 -0.8312 -0.7391 1.2594 3.402  
 98 -2.983 10.6157 0.5742 0.6649 -0.2937 -1.5696 -0.676 -0.4615 0.0351 -1.0443 -1.052 2.8146 4.6661

99 -2.35 9.1185 -0.1167 0.7113 -0.1322 -1.8639 -1.0895 -1.3382 -0.2475 -1.0466 -0.848 1.9016 3.2136  
 100 0.0957 6.8635 -0.5394 0.4321 -0.665 -3.5826 -2.0001 -1.1269 -0.4639 -0.9789 -0.7914 0.4856  
 0.6039  
 101 1.6157 5.7282 -0.0681 0.3401 -1.0939 -5.1472 -2.5558 -0.4735 0.0168 -1.0172 -0.6239 -0.2453  
 0.6597  
 102 0.401 6.4595 0.3584 0.6217 -0.7944 -4.6328 -1.7271 0.418 0.6632 -1.0559 -0.6407 0.6688 2.4252  
 103 -1.5787 7.0654 0.3378 1.3233 0.0949 -2.5397 -0.437 0.2215 0.7781 -1.2006 -0.5097 2.7707 4.5424  
 104 -1.9516 6.218 -0.1745 1.9325 0.7756 -0.3311 0.4625 -0.9269 0.0961 -1.1345 -0.4523 3.0443 4.8484  
 105 0.1265 4.1248 -0.5528 1.7968 0.6234 0.222 0.5454 -0.8172 0.0115 -0.9632 -0.1734 1.1239 1.9851  
 106 2.3643 2.5703 0.0522 1.6618 0.0198 -1.4578 -0.1173 -0.0274 0.325 -0.722 0.0688 -0.2942 0.3284  
 107 2.1085 2.7579 0.5354 1.0716 -0.4105 -2.9835 -0.7091 0.5924 0.6716 -0.8684 -0.1317 -1.0272 0.5324  
 108 -0.038 4.0237 0.7056 0.9481 -0.1471 -2.6226 -0.4135 0.9403 0.8519 -0.7689 -0.0737 0.2502 1.6916  
 109 -1.7032 4.2512 0.1605 0.9651 0.2549 -1.9922 -0.473 0.0303 0.1688 -0.6698 -0.0156 0.9788 2.0958  
 110 -1.2791 3.2329 -0.6975 0.7965 0.4137 -2.4012 -0.8166 -0.8796 -0.2821 -0.7824 -0.1788 -0.5323 -  
 0.8204  
 111 0.7517 1.7988 -0.7064 0.5819 -0.2258 -4.6582 -1.5153 -0.2594 0.13 -0.8603 -0.1942 -1.7239 -3.3347  
 112 1.5753 1.5258 -0.0001 0.2749 -0.7961 -6.9921 -2.143 0.4288 0.7079 -0.7979 -0.062 -2.0477 -2.2782  
 113 -0.537 2.7462 0.5719 0.2016 -0.8462 -7.2855 -1.7769 0.9131 1.3188 -0.7712 -0.0403 -1.1837 -  
 0.3672  
 114 -2.1278 3.2602 0.384 0.1757 -0.3066 -6.0389 -1.3754 0.5475 0.8671 -0.6043 -0.0186 0.9137 1.9456  
 115 -2.1118 2.2379 -0.6087 0.0106 0.1286 -4.3686 -1.2225 -0.9741 -0.6472 -0.7546 -0.5502 0.9084  
 1.9943  
 116 -0.0067 0.2604 -1.1097 -0.1537 0.0083 -4.6619 -1.4246 -0.9995 -0.5681 -0.5887 0.099 -0.514 -  
 0.7241  
 117 2.057 -1.0538 -0.5828 -0.2242 -0.4938 -6.1486 -1.6979 -0.1069 -0.0245 -0.4937 -0.3219 -1.4343 -  
 1.3808  
 118 1.7075 -0.5013 -0.1007 -0.1075 -0.5105 -6.2108 -1.3323 0.0037 0.187 -0.7512 -0.1892 -1.3039  
 0.0744  
 119 0.0704 0.5484 -0.021 0.2895 0.1319 -4.5789 -0.3632 0.2845 0.4647 -0.7629 -0.3147 0.9281 2.1326  
 120 -0.8444 0.56 -0.4331 0.8736 1.017 -2.9855 0.2507 -0.3867 0.1778 -0.8456 -0.3664 2.337 4.1398  
 121 -0.3936 -0.4668 -1.2924 0.3866 0.8261 -2.6626 -0.165 -0.9218 -0.6406 -1.1752 -1.0454 0.7749  
 1.5691  
 122 1.9856 -1.9507 -1.2577 0.0401 0.1838 -3.8796 -0.9712 -0.4708 -0.6291 -1.2239 -1.2815 -0.9706 -  
 0.8012  
 123 2.4741 -1.6093 -0.374 0.1137 -0.0076 -3.9417 -0.1446 0.2523 0.2122 -1.2731 -1.1487 -1.7569 -0.305  
 124 0.469 0.1423 0.1968 0.0948 -0.0683 -2.5792 0.7529 0.7374 0.5885 -1.4285 -1.311 -0.533 0.9449  
 125 -1.5776 1.1878 0.0969 0.1699 0.2524 -1.6787 0.8339 0.3386 0.1678 -1.1622 -1.252 1.2387 2.6468  
 126 -1.6154 0.6141 -0.6289 0.1058 0.2605 -1.6251 0.3467 -1.2161 -0.8507 -0.826 -1.1192 0.7248 1.33  
 127 0.5164 -0.8318 -0.8632 -0.3771 -0.3909 -3.2271 -0.5666 -0.6628 -0.4749 -0.7017 -0.9864 -1.1606 -  
 1.4966  
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 1.6077  
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366 6.6427 -14.4667 0.0 0.0 0.0 0.2671 0.1061 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0  
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